R E P O R T R E S U M E S

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AUTOMOTIVE DIESEL MAINTENANCE 1, UNIT XVI, I--USE AND CARE OF SMALL HAND TOOLS, II--PRINCIPLES OF THE POWER DIVIDER.

HUMAN ENGINEERING INSTITUTE, CLEVELAND, OHIO
REPORT NUMBER AM-1-16 PUB DATE 9 MAY 66
MINNESOTA STATE DEPT. OF EDUCATION, ST. PAUL
EDRS PRICE MF-$0.25 HC-$2.00 48P.

DESCRIPTORS- *STUDY GUIDES, *TEACHING GUIDES, *TRADE AND INDUSTRIAL EDUCATION, *AUTO MECHANICS (OCCUPATION), *DIESEL ENGINES, ADULT VOCATIONAL EDUCATION, TRANSPARENCIES, PROGRAMED MATERIALS, INDIVIDUAL INSTRUCTION, INSTRUCTIONAL FILMS, PROGRAMED INSTRUCTION, MOTOR VEHICLES, EQUIPMENT MAINTENANCE, KINETICS,

THIS MODULE OF A 30-MODULE COURSE IS DESIGNED TO DEVELOP AN UNDERSTANDING OF SMALL HAND TOOLS USED IN DIESEL ENGINE MAINTENANCE AND THE OPERATING PRINCIPLES AND MAINTENANCE OF POWER DIVIDERS (GEAR BOXES) USED IN DIESEL ENGINE POWER DISTRIBUTION. TOPICS ARE (1) UNDERSTANDING TORQUE AND HOW IT IS MEASURED, (2) REPAIRING AND REPLACING THREADED FASTENERS, (3) UNDERSTANDING THE OPERATING PRINCIPLES (POWER DIVIDERS), AND (4) POWER DIVIDER REMOVAL. THE MODULE CONSISTS OF A SELF-INSTRUCTIONAL BRANCH PROGRAMED TRAINING FILM "PRINCIPLES AND APPLICATIONS OF BASIC MACHINES" AND OTHER MATERIALS. SEE VT 005 655 FOR FURTHER INFORMATION. MODULES IN THIS SERIES ARE AVAILABLE AS VT 005 655 - VT 005 684. MODULES FOR "AUTOMOTIVE DIESEL MAINTENANCE 2" ARE AVAILABLE AS VT 005 685 - VT 005 709. THE 2-YEAR PROGRAM OUTLINE FOR "AUTOMOTIVE DIESEL MAINTENANCE 1 AND 2" IS AVAILABLE AS VT 006 006. THE TEXT MATERIAL, TRANSPARENCIES, PROGRAMED TRAINING FILM, AND THE ELECTRONIC TUTOR MAY BE RENTED (FOR $1.75 PER WEEK) OR PURCHASED FROM THE HUMAN ENGINEERING INSTITUTE, HEADQUARTERS AND DEVELOPMENT CENTER, 2341 CARNEGIE AVENUE, CLEVELAND, OHIO 44115. (HC)

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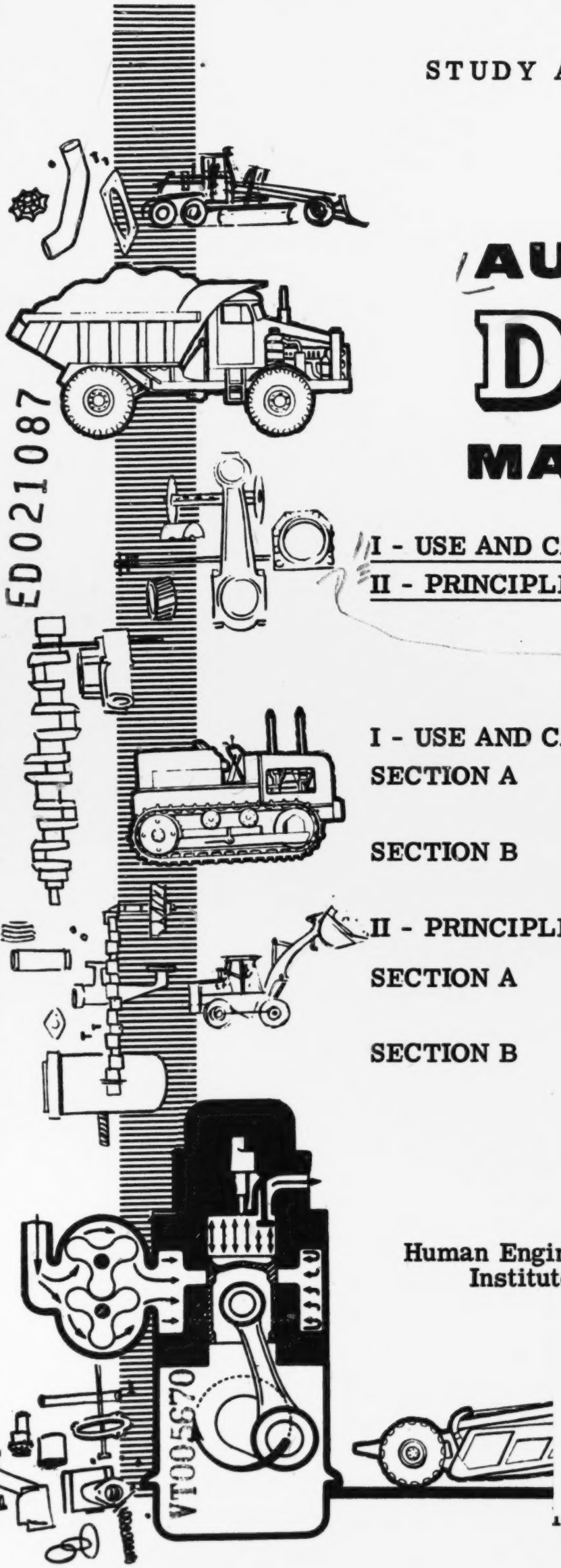

STUDY AND READING MATERIALS

AUTOMOTIVE DIESEL MAINTENANCE 1

I - USE AND CARE OF SMALL HAND TOOLS
II - PRINCIPLES OF THE POWER DIVIDER

UNIT XVI

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This unit is divided into two parts. The first part covers the proper use and care of small hand tools which is vital to an organized and efficient repair shop. The second half covers a very brief discussion about the power divider.

I -- USE AND CARE OF SMALL HAND TOOLS

SECTION A - UNDERSTANDING TORQUE AND HOW IT IS MEASURED

Small hand tools make up a large portion of the diesel mechanic's daily work and it is to his advantage to know when and how to use them. Tools become more valuable and are appreciated more when the person who uses them knows what is going on as he uses them.

TORQUE -- Whenever we use a wrench to tighten or loosen a nut or bolt we apply a twisting effort known as torque. The amount of torque we apply to a bolt or nut will determine just how tight or loose it will be. If too much torque is applied, the bolt may break. If too little torque is applied, the assembly will not be securely fastened.

The amount of torque applied to a nut or bolt is determined by the distance from the center point of the threaded fastener to the point where you pull on the wrench (lever arm), and by how much force, in pounds, you apply. (See Figure 1).

The lever arm may be measured in feet, in which case the torque is in foot pounds. Often it is more convenient to measure the lever arm in inches, in which case the product of lever arm

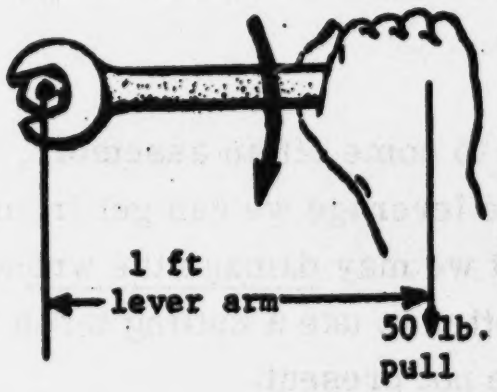


Fig. 1 Here torque is 50 ft. lbs. or 600 in. lbs.

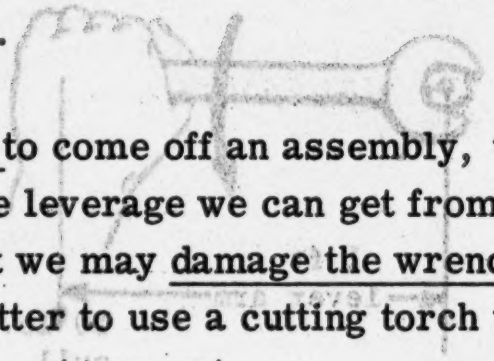
in inches by the force in pounds gives the torque in inch pounds.

If a force of 50 lbs. is applied on the wrench 6 in. from the center of the fastener, torque created on the fastener would be 50 pounds x 6 in. = 300 in. lbs. If the 50 pound force is applied 12 inches from the center of the fastener, torque would be doubled although the force remains the same. The torque would be: 50 pounds x 12 in. = 600 in. lbs. or 50 pounds x 1 ft. = 50 ft. lbs. If we doubled the force applied on the wrench to 100 pounds, the torque would be 100 lbs. x 6 in. = 600 in. lbs. or 100 lbs. x 1/2 ft. = 50 ft. lbs. Torque is increased by an increase of either the force or length of the crank. The formula then, would be:

torque = force x distance

Torque, any force in fact, can be applied without work being done. In the above example the 50 lb. force exerted moves the fastener to a certain position and then it stops turning when it is tightened. Torque is still being exerted after the fastener stops turning, but since the force continuing to be applied does not continue to move the fastener through any distance, no work is done. A higher torque is needed to start the fastener moving again.

From the above example, we noticed that when we doubled either the force applied or the distance, the torque was doubled. We should remember this whenever we are tempted to use a piece of pipe on the end of a wrench.



If a nut has to come off an assembly, we may want to use a pipe to increase the leverage we can get from a wrench. We should remember though, that we may damage the wrench or twist off the bolt or stud. It would be better to use a cutting torch to remove the fastener, if fire hazards are not present.

WRENCHES are made to tighten or loosen nuts, bolts, screws, and pipe plugs. They should never be used as hammers or pry bars. Special wrenches are made to grip round stock such as pipe, studs, and rods. Spanner wrenches are used to tighten or loosen cover plates, rings, and couplings.

Various open end wrenches are shown in Figure 2. They usually are double ended wrenches, although some have a single open end. These wrenches are forged from chrome vanadium steel and heat treated for added strength. The size of the opening between the jaws is usually stamped near the jaws. The openings are from 0.005 inch to 0.015 inch larger than the size marked, so that they will easily slip onto bolt heads or nuts of that size.

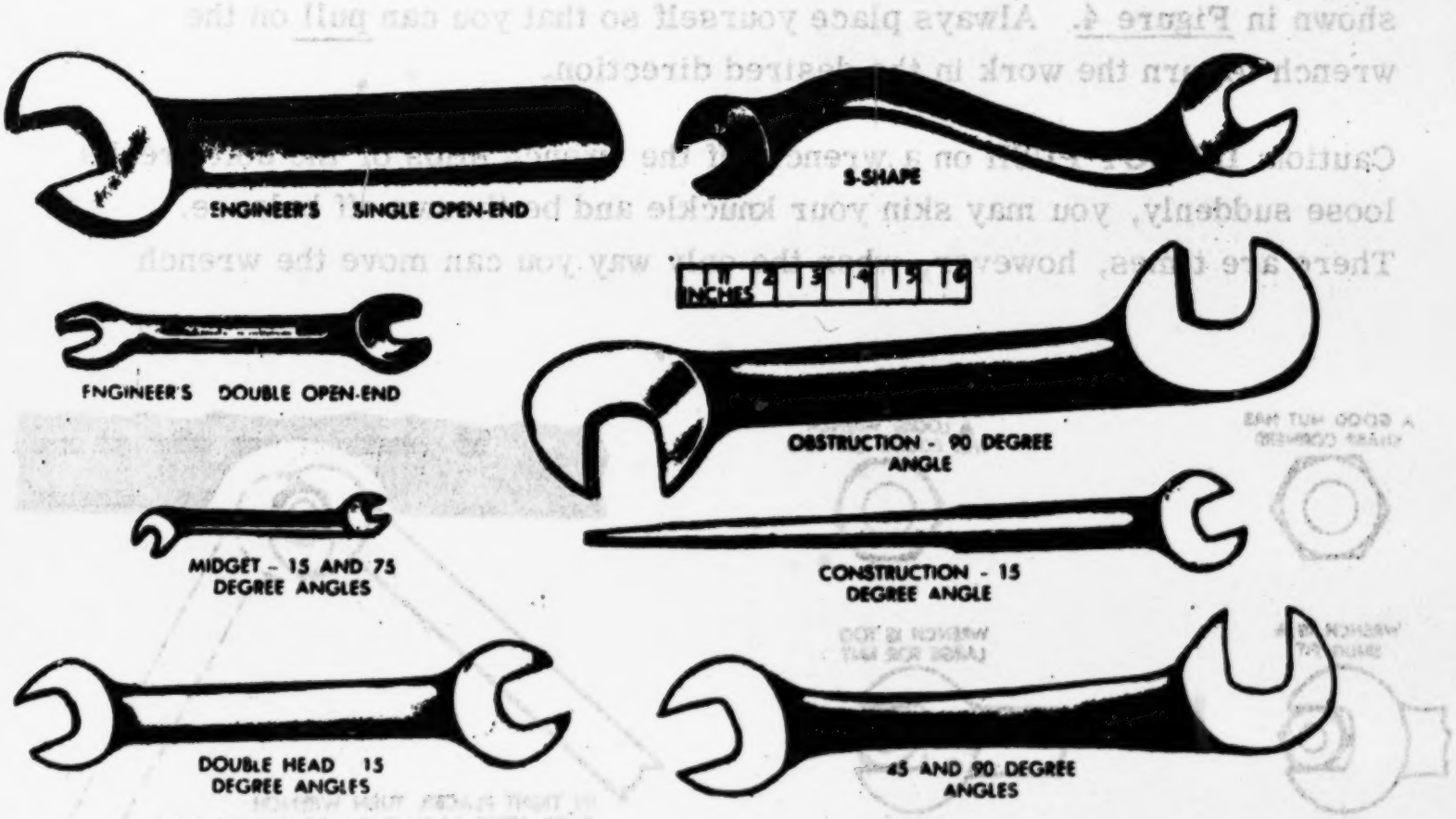


Fig. 2 Open end wrenches.

Open end wrenches are made in many different sizes, ranging upward in steps of 1/32 inch, starting with 5/32 inch, and going up to 1 3/4 inches. The common open end wrench is made with the ends at an angle of 10° to 23° to the body of the wrench so that the user can work in close quarters. Other special open end wrenches may have the ends at an angle of 45, 60, or 90 degrees, or a combination of two angles. Wrenches with larger openings are made longer and heavier to increase leverage and strength.

It is important for a wrench to be a snug fit on a nut or bolt head. If it is too loose, the wrench will slip and will round the corners. Make certain that the wrench fits squarely on the sides of the nut or bolt head, as shown in Figure 3. Offset open end wrenches make it possible to turn a nut or bolt that is recessed, and in limited quarters where there is little space to swing the wrench. Turn the wrench over after each swing so that the opposite face is down, and the angle of the wrench opening is reversed as shown in Figure 4. Always place yourself so that you can pull on the wrench to turn the work in the desired direction.

Caution: DO NOT PUSH on a wrench. If the wrench slips or the bolt breaks loose suddenly, you may skin your knuckle and be thrown off balance. There are times, however, when the only way you can move the wrench

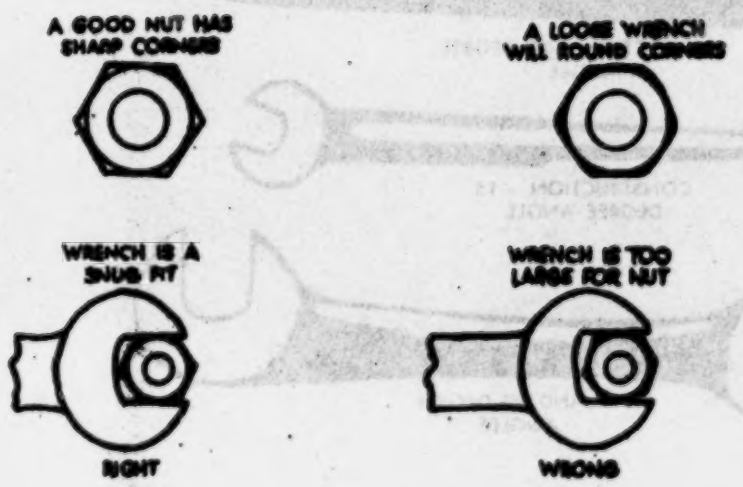


Fig. 3 Right and wrong way of fitting open end wrench to nut.

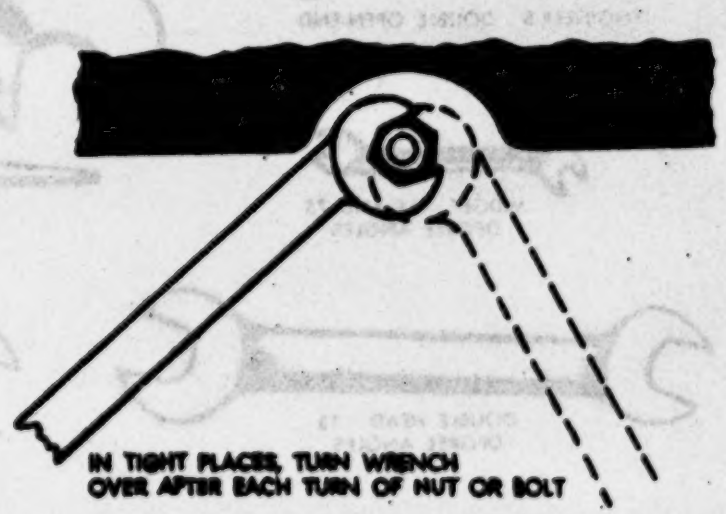


Fig. 4 Using open end wrench in tight spot.

is by pushing it. In this case, do not wrap your fingers around it. Push it with the palm of your hand and hold your hand open to keep your fingers out of danger.

Box wrenches, Figure 5, are so named because they completely surround or "box in" the bolt head or nut. The opening in a box wrench contains 6 or 12 notches, called points, arranged in a circle. The box wrench is a safer tool to use than the open end wrench, since it will not slip off the work. As little as one-twelfth of a turn can be taken at each stroke, if necessary in close quarters. Box wrenches may have straight handles; they may be offset; or the box end may be offset. Box wrenches are available in the same sizes as are open end wrenches, and usually have two openings, one opening usually 1/16 inch larger than the other. A ratchet box wrench usually has two 12 point openings and it not automatically reversible. However, it can be turned around to do both tightening

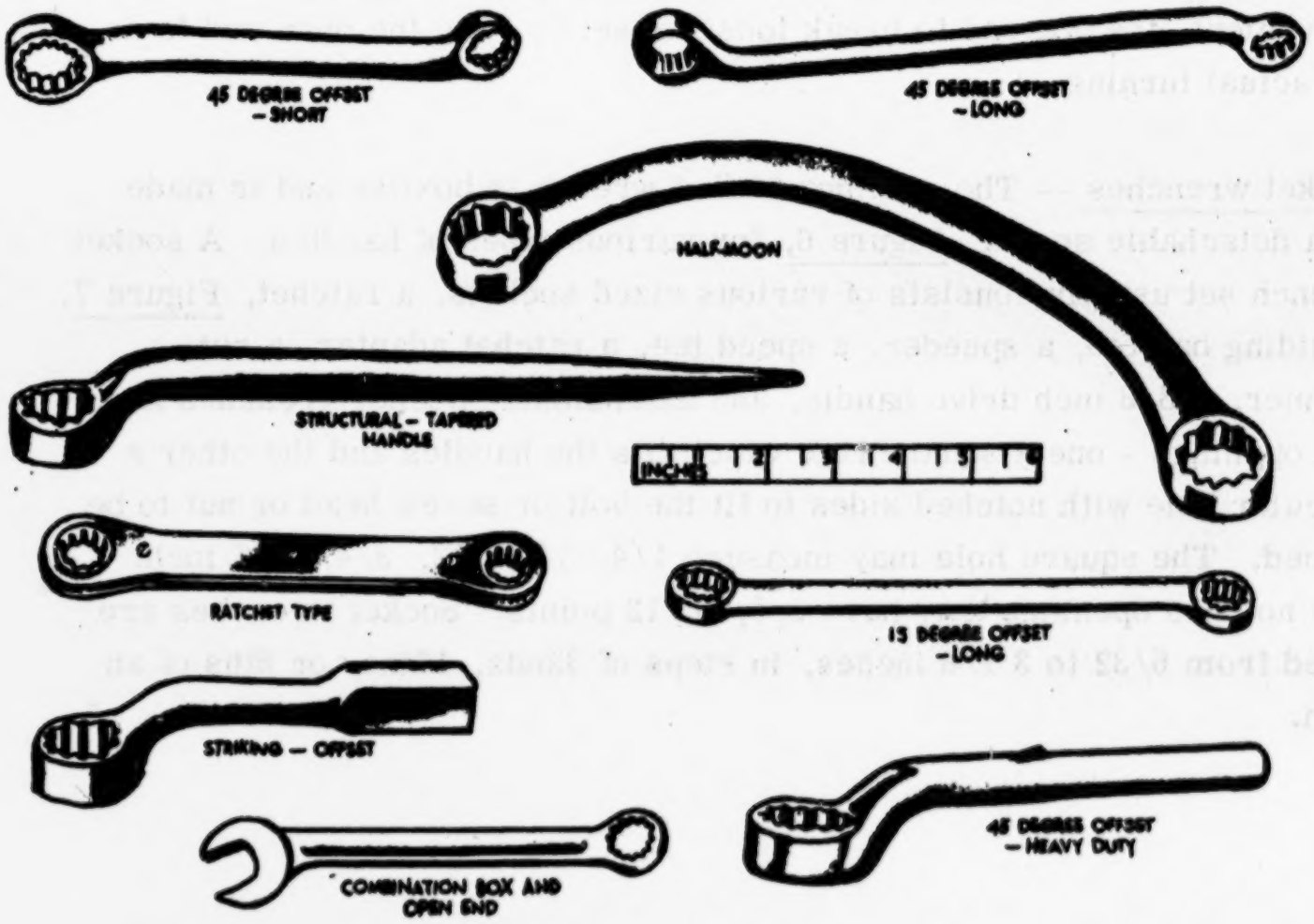


Fig. 5 Box and combination wrenches.

and loosening operations. Being of sturdy, thin construction, they are convenient for working in limited spaces. Ratchet box wrenches range from 3/8 and 7/16 inch openings to 3/4 and 7/8 inch openings.

Combination wrenches, Figure 5, have one open end and a box wrench at the other end. They may be made with any combination of sizes, offsets, and angles.

When using box wrenches, always select the size wrench that fits the nut or bolt head. A swing through an arc of 15 degrees is enough to continuously loosen or tighten a nut or bolt. Since a box wrench cannot slip off a nut, it is ideal for loosening tight nuts and bolts, and for setting them up. After a nut is started, it can usually be tightened more quickly with an open end wrench than with a box wrench. For this reason, combination box and open end wrenches are very popular and are more convenient, the box end to break loose or set up, and the open end to do the actual turning.

Socket wrenches -- The common socket wrench is boxlike and is made as a detachable socket, Figure 6, for various types of handles. A socket wrench set usually consists of various sized sockets, a ratchet, Figure 7, a sliding bar tee, a speeder, a speed tee, a ratchet adapter, a nut spinner, a 3/8 inch drive handle, and extensions. Socket wrenches have two openings - one a square hole which fits the handles and the other a circular hole with notched sides to fit the bolt or screw head or nut to be turned. The square hole may measure 1/4, 3/8, 1/2, 3/4, or 1 inch. The notched openings may have 6, 8, or 12 points. Socket wrenches are sized from 5/32 to 3 1/8 inches, in steps of 32nds, 16ths, or 8ths of an inch.

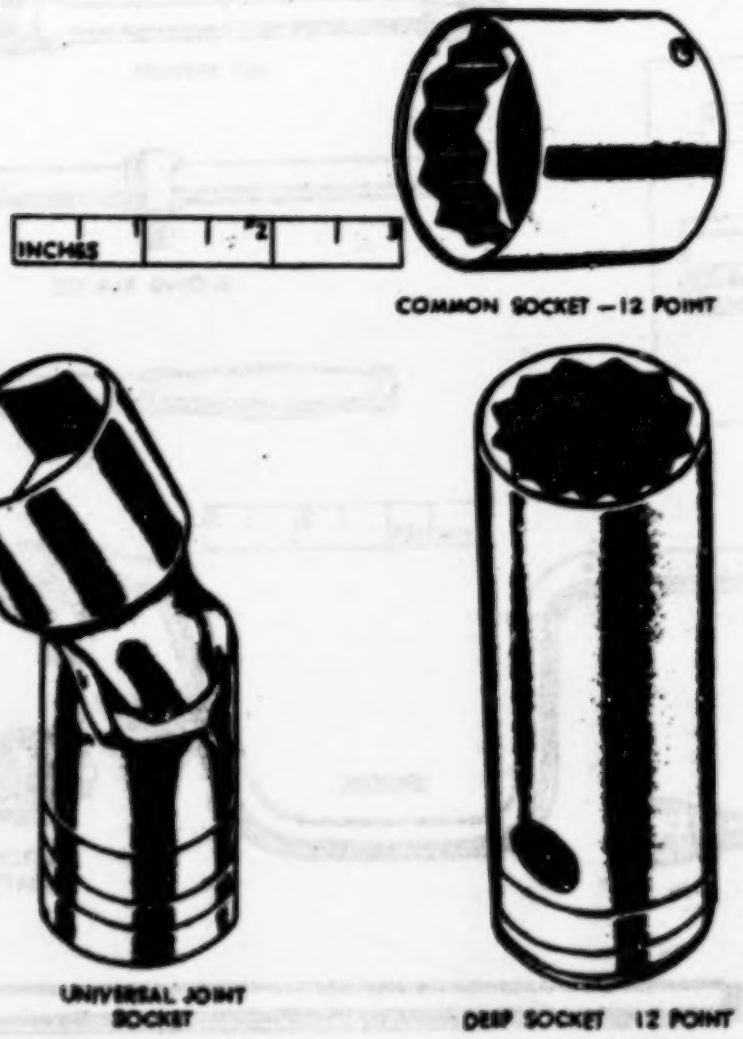


Fig. 6 Socket wrenches.

To use a socket wrench, select the proper socket and push it onto the handle which is best suited to the job. If there is room to swing it, use the ratchet handle. By using the ratchet handle, much time is saved in that it can be swung back and forth to turn the nut, eliminating the need to raise the socket from the nut at the end of each swing. A nut spinner handle, Figure 7, also saves time. When a tight nut is to be loosened or a nut it to be set up, the handle can be swung at right angles to the socket to provide the most leverage. At the point where the nut turns easily, the handle can be swung to a vertical position and twisted rapidly between the

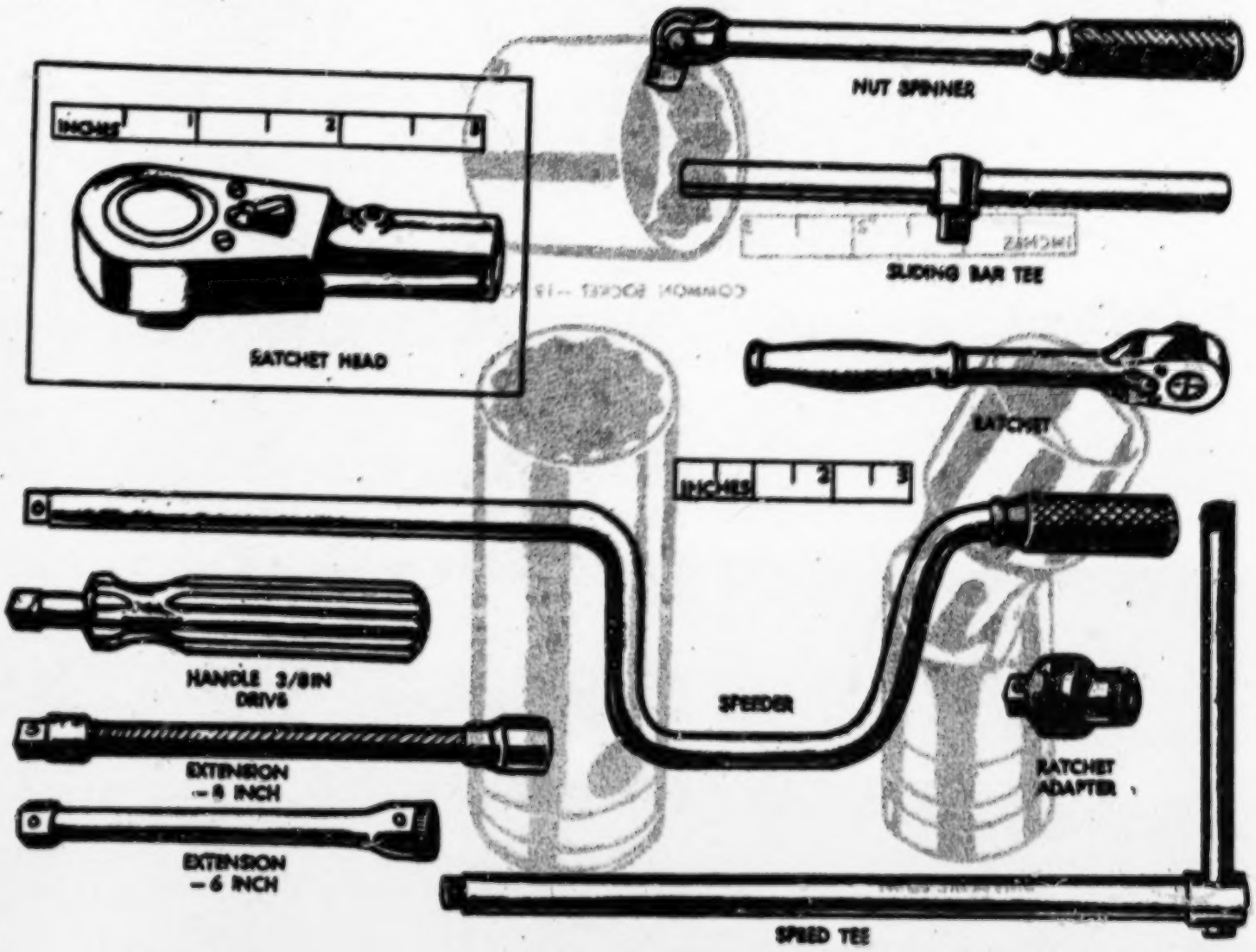


Fig. 7 Socket wrench ratchets, handles and extensions.

fingers in the same manner as a screwdriver. A universal joint socket wrench, Figure 6, makes it possible to turn nuts where a straight wrench could not be used unless some part of the machine or equipment is removed.

The single open end adjustable wrench, Figure 8, has one fixed end non-adjustable jaw and one stationary jaw. A knurled nut is rotated to bring the movable jaw up to fit the nut or bolt head.

When using this wrench, always place the wrench on a nut or bolt so that the force used to turn it is applied to the stationary jaw side of the wrench as shown in Figure 8. After placing the wrench in position, tighten the knurled adjusting nut until the wrench fits the nut or bolt head as tightly as possible. If it does not fit tightly, it will slip; it may cause an injury to your hand or round the corners of the nut or bolt head.

A torque wrench, Figure 9, is used for work requiring a particular force (torque) to tighten bolts, nuts, cap screws, etc., to a desired degree of pressure. A dial or scale calibrated in foot-pounds indicates the degree of torque placed on the work. The pointer moves to the right or left of zero, depending on the bolt (left or right hand threads) being tightened. These wrenches are made in several sizes, with 1/4, 1/2, or 3/4 inch square drive to receive socket wrenches, and capacity up to 1,000 foot pounds.

The torque wrench lets us set up a nut or bolt when the force applied to the handle reaches the specified limit. Manufacturers' instructions specify these limits of turning force. Cylinder head nuts and bolts, rod bearing caps, and other places on internal combustion and diesel engines usually require torque wrench limits. Select the proper size socket wrench and attach to torque wrench square drive. Place socket wrench on work and pull the torque wrench handle in the desired direction to tighten the work.

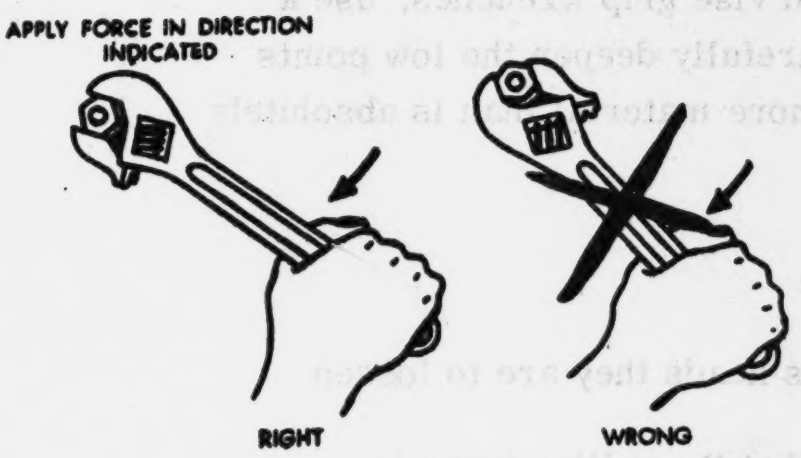


Fig. 8 Using adjustable wrenches.

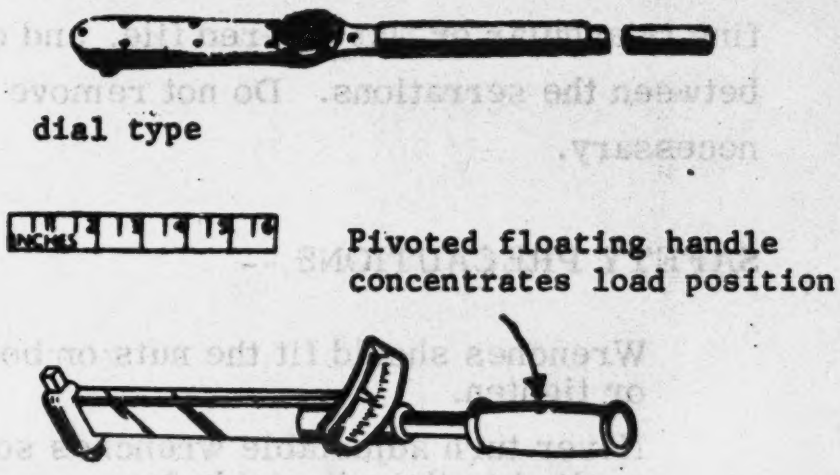


Fig. 9 Torque wrenches.

The tightening torque will be indicated on the dial or scale, depending on the type of torque wrench used.

Different types of torque testers are available for testing the accuracy of torque wrenches. Where the amount of torque to be applied is of critical importance, the wrench should be tested for accuracy before it is used.

CARE OF WRENCHES - Clean all wrenches after use. Apply a thin film of oil to metal parts of all wrenches prior to storing. Wrenches that come in sets, such as socket wrenches, should be returned to their cases after being used, so that the set is kept intact. The torque wrench, in particular, must be carefully placed in its box to prevent damage to the dial or scale.

MAINTENANCE OF WRENCHES - Fixed open end and adjustable open-end wrenches having damaged jaws can be made serviceable by grinding and/or filing. When attempting this repair, finish grind or file the jaw opening of the fixed open end wrench to the next largest standard size. Jaw faces must be flat and parallel. Use a part of known size, or a gauge block, to test for correct size and parallelism. Dip jaws in water frequently when grinding, to preserve the temper which can be lost because of over heating.

To renew the serrations in auto, pipe, and vise grip wrenches, use a fine triangular or flat tapered file, and carefully deepen the low points between the serrations. Do not remove more material than is absolutely necessary.

SAFETY PRECAUTIONS --

Wrenches should fit the nuts or bolts heads they are to loosen or tighten.

Never turn adjustable wrenches so that the pulling force is applied to the adjustable jaw.

Do NOT use a pipe, or extend the handle in any way, to increase the leverage on a wrench, unless it is absolutely necessary.

Apply penetrating oil to rusted nuts and bolts that resist turning. Allow time for oil to penetrate before attempting to turn.

Do not strike wrenches with hammers to tighten or loosen nuts or bolts.

Do not exert a hard pull on a pipe wrench until it has a firm grip on the work.

Remember to PULL on the wrench when possible, in order to protect your knuckles in case the wrench slips. When possible keep the palm open when you have to push on the wrench handle, to avoid smashed knuckles. Always take the proper stance to avoid slipping or losing your balance if the wrench should yield suddenly.

Always keep the wrench in good condition: clean, and free from oil or grease.

SECTION B - REPAIRING AND REPLACING THREADED FASTENERS

REPAIRING EXTERNAL (MALE) THREADS - To repair male threads we may be able to use the rethreading die seen in Figure 10. This die is used principally for dressing over bruised or rusty threads on screws and bolts. These dies usually are hexagon in shape and can be turned with a socket, box, open end, or any wrench that will fit.

If we are working in too close quarters to use a rethreading die, or if we don't have a die available we may be able to repair the stud with a triangular shaped file. Using the file, we follow the thread around the stud and file off the threads or parts of threads that have been bent, smashed, or "banged-up". Then we clean the

Fig. 10 Rethreading die.

stud so that the filings and dirt won't cause the nut to again bind up on the stud. This is a good technique for repairing a stud IF enough threads or parts of threads are left to give the surfaces being clamped together the desired strength.

REPAIRING INTERNAL (FEMALE)THREADS - Rather than go get a new nut, many times it is quicker and easier to run the nut over a tap. This will remove any bent-over sections of the thread and do this in much the same way that a file removes damaged threads on external threads.

A tap is a hardened and tempered steel tool. It has a thread cut on it, and this thread is partly cut away by flutes running lengthwise on the tool, to form cutting edges. See Figure 11. Naturally, a tap must have the same size thread as the nut. For example a 1/2-13 NC tap must be used to repair a 1/2-13 NC nut.

The parts should be cleaned and greased or oiled before reassembly. Use whatever procedures and equipment are available in the plant. Caution: take approprite precautions against fire if kerosene is used to clean up the parts. If compressed air is used precautions should be taken to avoid blowing particles all over the department with the compressed air.

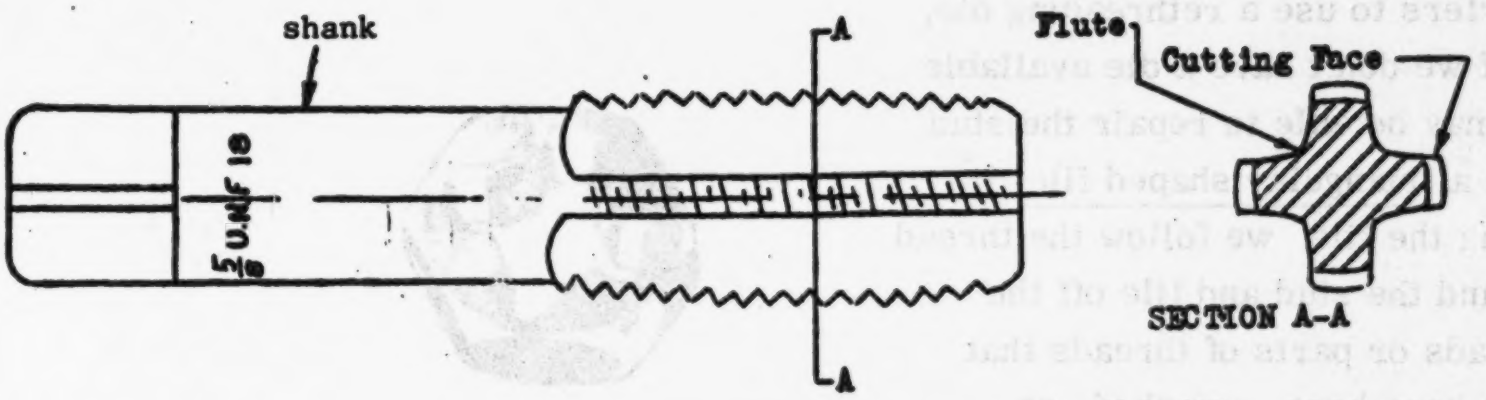


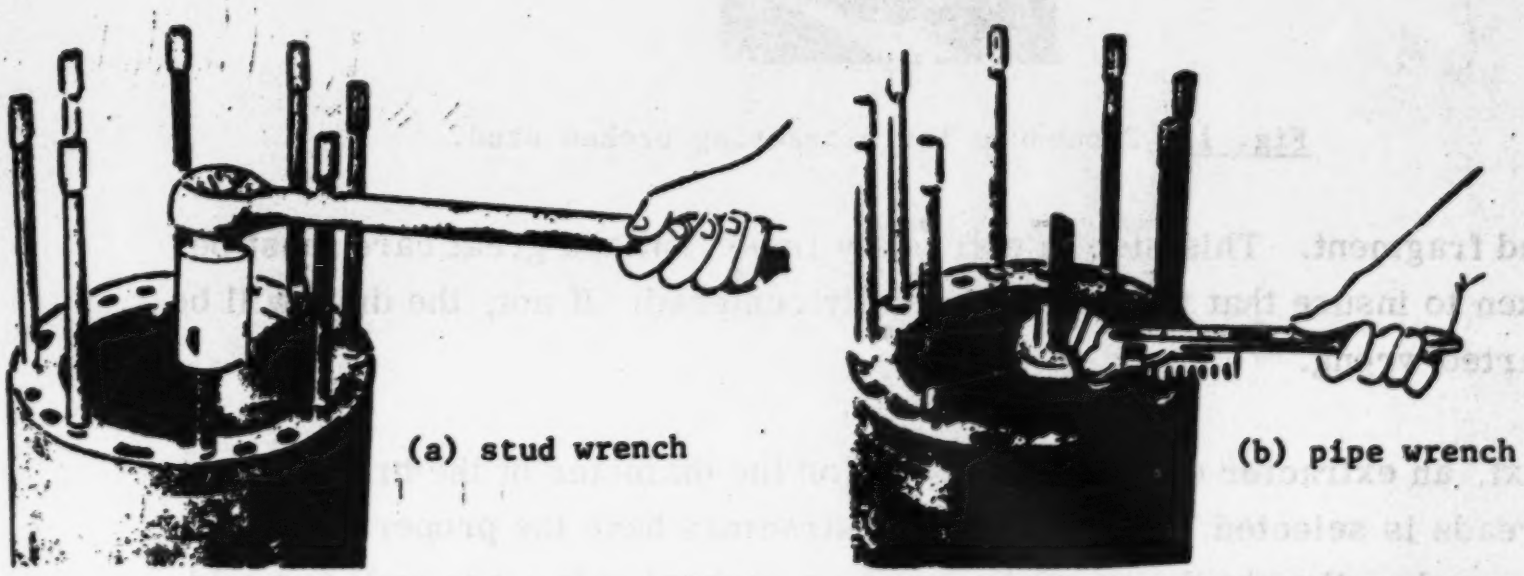
Fig. 11 Parts of a four-fluted tap.

EXTRACTORS (EASY-OUT) -- When a stud or bolt breaks or is stripped, it's remains must be removed and a new stud or bolt installed.

Removal of the remains of a broken stud or bolt may be most difficult, even if the proper tools are on hand. However, removal may not be possible unless the need for tools of this nature is foreseen. The exact procedure to be used for stud or bolt removal depends upon the type of fracture. If breakage occurs at the upper threads or high enough on the shank, it may be possible to grasp the stud with a stud wrench or pipe wrench. Figure 12 illustrates these two methods of removal.

When breakage occurs too near the surface to grasp it with a wrench, we must try some other means of removal. The most successful method of removal in such cases is to use a screw extractor. This device is a tapered screw with prominent sharp flutes, and a lug for a wrench. The extractor is made of hardened alloy steel.

It is extremely important that the correct procedure be employed when using such a device to remove a stud or bolt fragment. The procedure shown in Figure 13 is recommended. The first step is to center punch the



(a) stud wrench (b) pipe wrench

Fig. 12 Two methods for removing a broken stud.

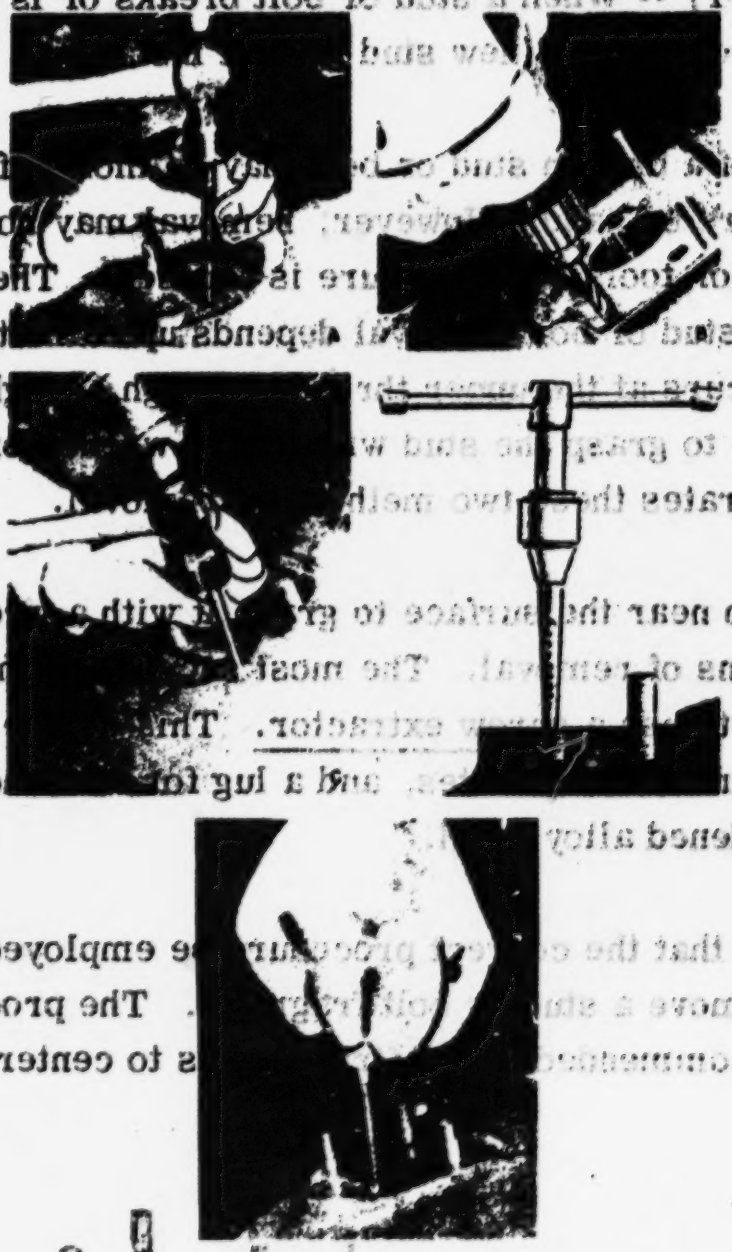


Fig. 12 Procedure for extracting broken stud.

stud fragment. This step is extremely important and great care must be taken to insure that the [illegible] exactly centered. If not, the drill will be started wrong.

Next, an extractor of the proper size for the diameter of the broken stud threads is selected. [illegible] all extractors have the proper [illegible] size stamped on the shank near the top. As a general rule, it is well to avoid the use of an extractor requiring a drill that would leave a wall of less than 1/16 inch thickness (in addition to the thread thickness). Upon selection of

the proper size drill, the stud fragment is drilled to a depth sufficient to seat the extractor properly.

The extractor is seated by holding it as nearly as possible in line with the drilled hole, and striking it one sharp blow with a hammer. A larger hammer should be used for a larger extractor.

Extraction is accomplished by placing a suitable wrench on the extractor lug and turning it counterclockwise. Care must be exercised to prevent cocking, and consequent disengagement, of the extractor during the turning operation.

CHISELS - Flat cold chisels are the ones most frequently used by mechanics but the other types shown in Figure 14 have helped many a mechanic out of a "tight spot" when the right tools to do the job were not at hand.

For example, there are several types of extractors for removing broken studs or bolts. If we have to remove a broken stud or bolt and have a set of these extractors, the job will be comparatively simple. If we don't have the extractor, or if the extractor will not work because the stud is too tight, it usually can be removed with the aid of a chisel.

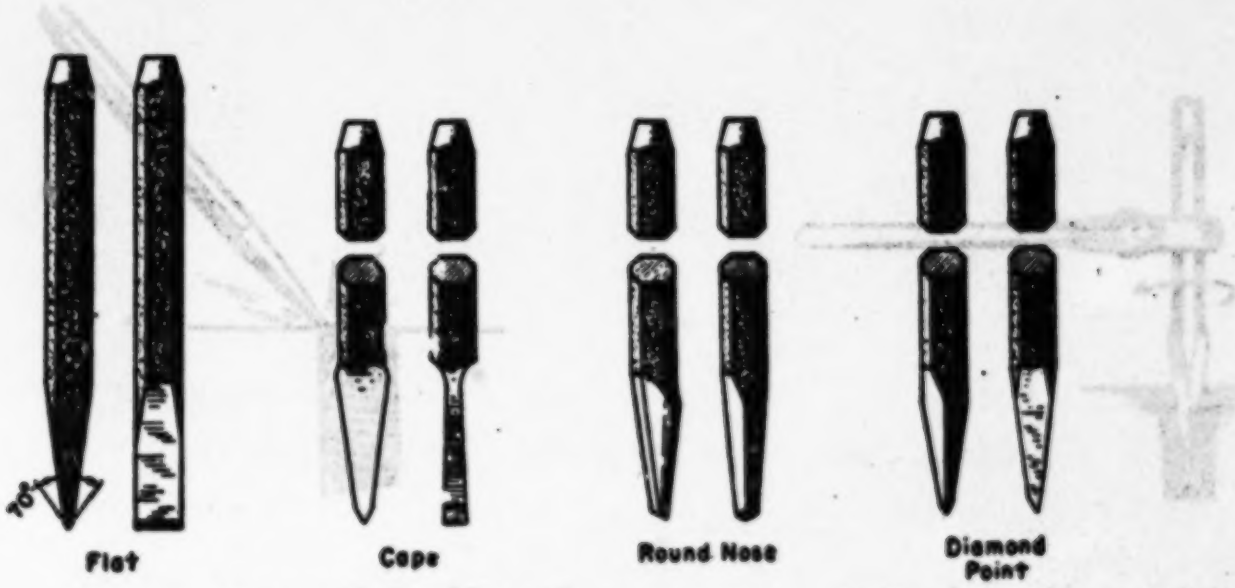


Fig. 14 Types of chisels used in maintenance.

Here are two methods -- "tricks of the trade" -- which are useful in such cases:

In either case, we put a center punch mark exactly in the center of the stud, then drill a hole down into the stud, large enough so that practically all that remains of the stud is a thin sleeve with the threads on it. Do not use a drill so large that it will cut into the threads. Next, use a diamond point chisel and tap it into the hole. Put an adjustable wrench on the square of the chisel and back out the broken stud as shown in Figure 15.

If a diamond point chisel of the correct size is not available, we may be able to use a round nose chisel and start breaking the stud threads out of the tapped hole, Figure 16, and thus collapse the remaining portion of the stud so that it can be removed.

The diamond point chisel isn't intended for use as a stud extractor, but like many other instances that might be considered as misuse of a tool, it's a way to get the job done if the right tool is not available. Always be sure that the tool being used as a substitute is used carefully so as not to damage or destroy it, or injure you or other workmen around you.

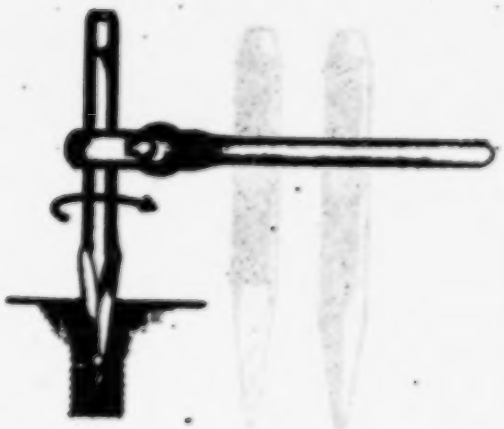


Fig. 15 Using a diamond point chisel to remove broken stud in emergency.

Fig. 16 Collapsing remaining part of broken stud.

USING CHISELS -- Always use a chisel that is big enough for the job. Also use a hammer that is heavy enough for the size of the chisel -- the larger the chisel, the heavier the hammer.

Ordinarily,, a chisel should be held in the left hand with the thumb and first finger about an inch from the upper end of the chisel. Hold the chisel with a steady but rather loose grip, with finger muscles relaxed. If you miss the chisel with the hammer and strike your hand it will slide down the chisel and lessen the effect of the hammer blow.

Another method of holding a chisel is sometimes used. Some perfer to hold it in the same manner (palm up) as you would grasp it if it were being handed to you. The thumb and first finger would then be placed about one inch from the tapered portion of the chisel. This lets you more easily see the work and the cutting edge of the chisel.

FILING THREADS -- You'll remember that we discussed using a triangular shaped file to repair damaged threads. In using a file, there are some points we should be aware of.

Before you try to use any file, it should always be equipped with a tight fitting handle. Often the end of the tang is quite sharp. If you are using a file without a handle, and the file meets an obstruction and is suddenly stopped, the pressure of your hand against the end of the tang may result in a bad cut.

To put a handle on a file, first make sure the handle is the right size and that the hole is large enough for the tang. Insert the tang of the file into the hole in the handle, then tap the back end of the handle on the bench or a flat surface on the vise as in Figure 17. Make sure that the handle is on straight.

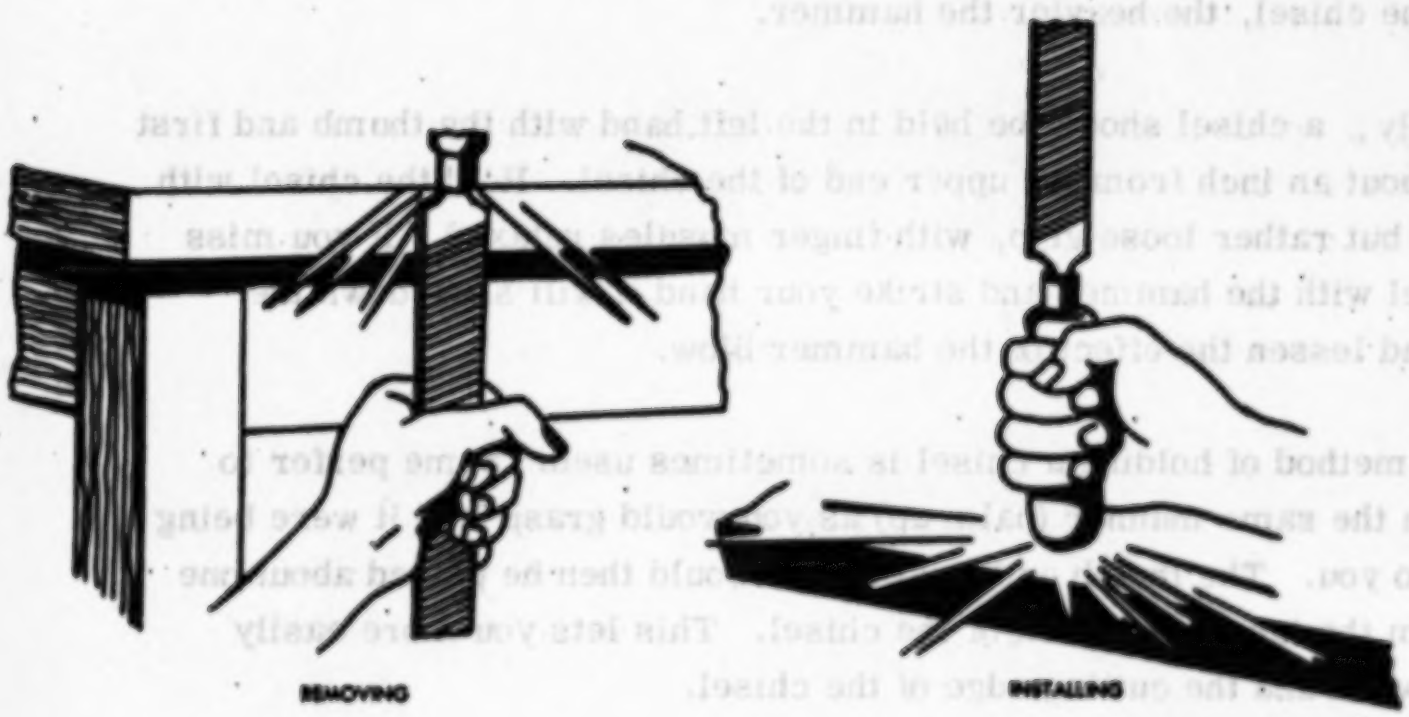


Fig. 17 Removing and installing a file handle.

To remove a file handle, hold the handle in your right hand and hold the file with your left hand and give the ferrule end of the handle a sharp rap against the edge of the bench or the side of a vise jaw.

Whenever possible, the part to be filed should be clamped rigidly in a vise. In using a file, remember that the teeth are made to cut in one direction only -- when the file is being pushed forward. All pressure of the file against the work should be relieved on the back stroke. Holding a file against the work on the back stroke serves only to help dull the cutting edges of the teeth. The preferred method of using a file is to raise it off the work before drawing it back. Files stay sharp longer when used this way.

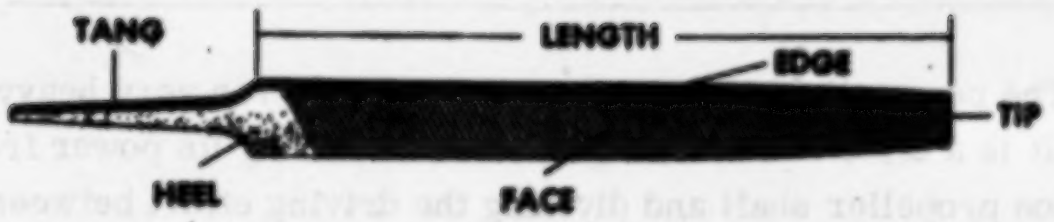


Fig. 18 Parts of a file.

Never use a file for prying. The tang end, Figure 18, is soft and bends easily. The body of the file is hard and very brittle. A light bending force will snap it in two.

A final and very important precaution is -- never hammer on a file. This is very dangerous because it may shatter, with chips flying in every direction.

File racks like those shown in Figure 19 help give more mileage to files. Throwing them in a drawer as is ofter done, will damage the many sharp edges.

Fig. 19 Storage racks for files.

II -- PRINCIPLES OF THE POWER DIVIDER

SECTION A -- UNDERSTANDING THE OPERATING PRINCIPLES

PURPOSE -- The power divider is used on large trucks for very heavy applications. It is a distribution unit (gear box) receiving its power from the transmission propeller shaft and dividing the driving effort between two output shafts, each of which is connected to one of the two driving axles. Figure 20 shows a simple torque divider hook up.

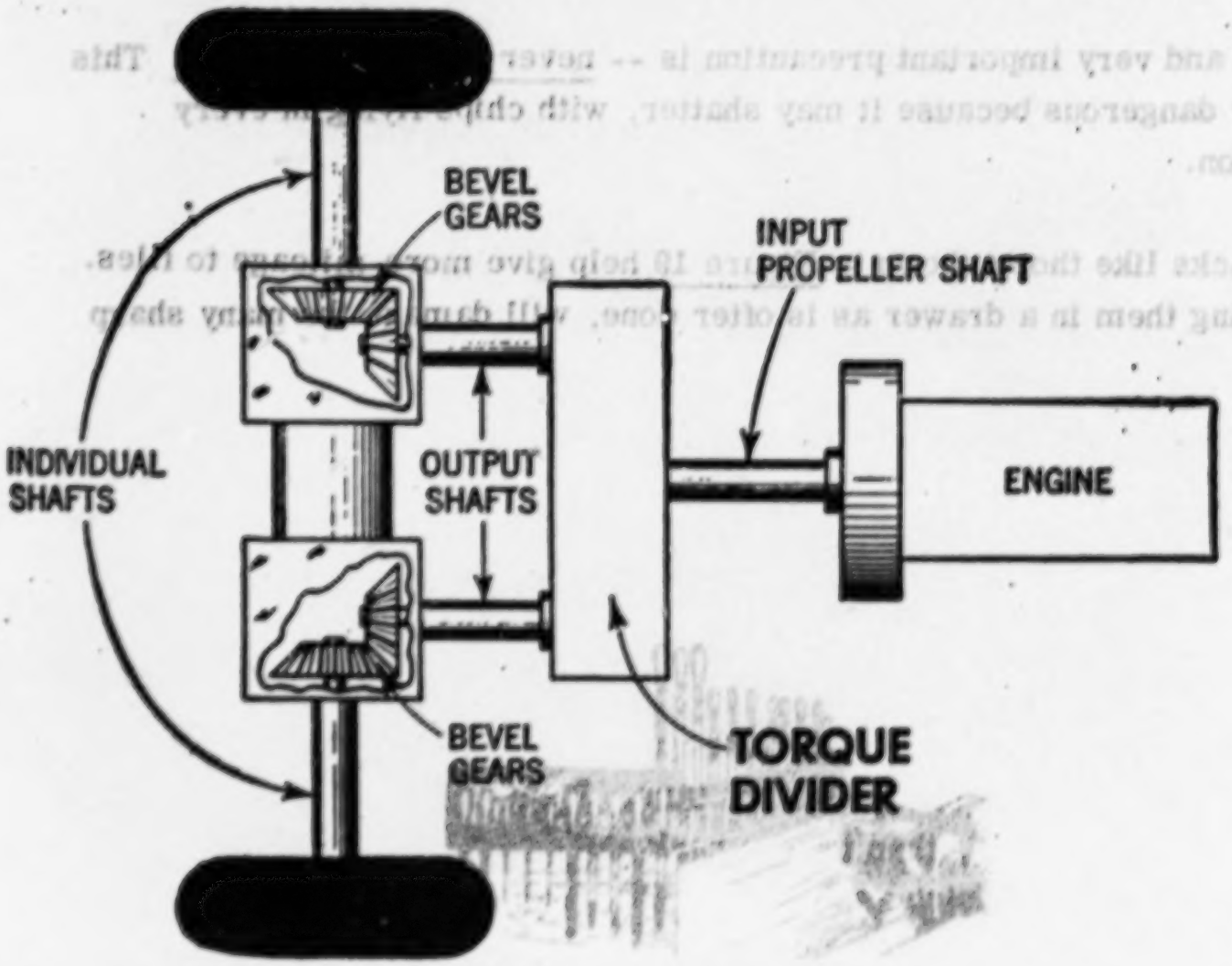


Fig. 20 Power divider and hook up.

CONSTRUCTION -- The center shaft, which is the main driving shaft getting its power from the transmission, carries an inter-axle differential which distributes driving torque to the two output shafts in proportion to the traction available at the rear wheels.

A control valve in the truck cab is used in conjunction with the power divider whenever the wheels of one drive axle are slipping. The control valve actuates a lockout air cylinder which,in turn forces a sliding collar to mesh with the input shaft rear gear. This locks both input shaft gears to the input shaft, transmitting equal power to both drive axles.
CAUTION: The control valve must be actuated only when the transmission, is in neutral and the vehicle is stationary and only when necessary.

Figure 21 shows a dual drive unit hook up using a power divider. As described above, power is transmitted to the axles from the power divider, containing an inter-axle differential which can be locked out by the operator as required.

SECTION B -- POWER DIVIDER REMOVAL FROM TRUCK

STEAM CLEANING -- Move the truck to the steam cleaning area and clean area to be worked on. CAUTION: Use face shield when steam cleaning where applicable.

Move truck into the work shop area. Be sure the proper tools required are available, and that there is enough space to work.

Remove the drain plug from the bottom of the power divider and drain oil into the waste oil container. Be sure all oil is removed. Clean up any spillage.

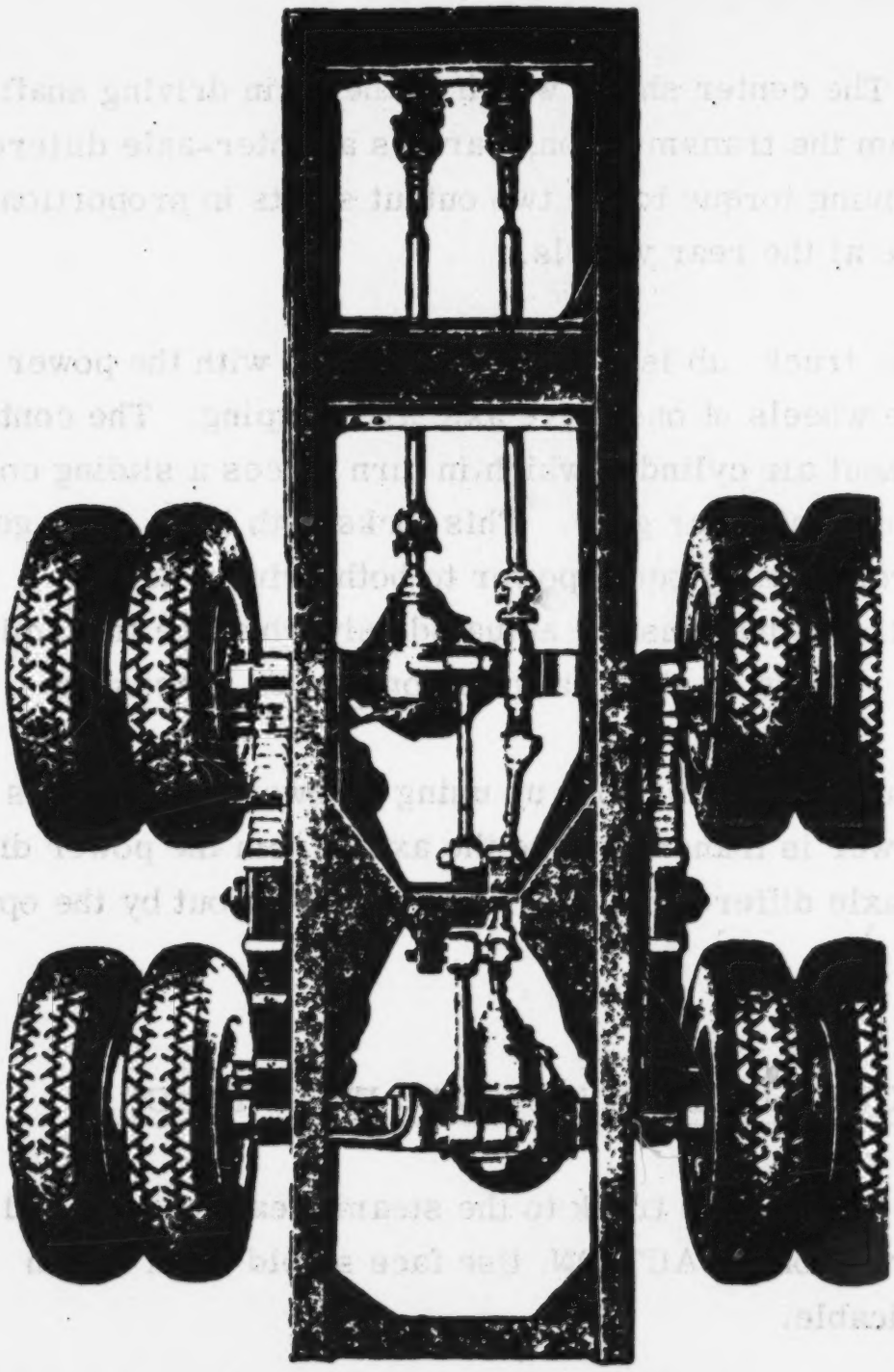


Fig. 21 Power divider hook up using a dual drive.

Remove the nuts and bolts from output flanges of the power divider output flanges and lower the ends of the drive lines. Saddles and jacks may be necessary to use here for long shafts.

Disconnect air hose from the lockout air cylinder. Remove cotter pin and clevis pin from the yoke of the lockout air cylinder. Remove the two nuts and lock washers and remove the cylinder.

Support the power divider by using a floor jack before continuing with removal.

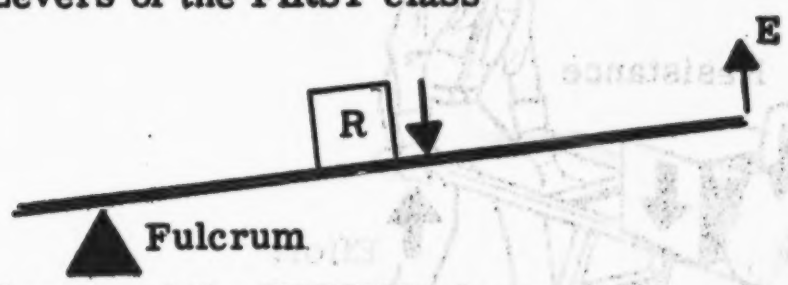
Loosen clamping bolt on trunnion mounting at rear of power divider. Remove four nuts, lock washers, bolts, and trunnion mounting.

Remove two elastic stop nuts and bolts which hold the power divider to the support. Slide the unit to the rear to disengage driveline from the input shaft of the power divider. Remove the power divider from under the unit. Place the unit on a cart and take to rebuild area.

This has been a brief explanation of how the power divider works and how to remove it from a truck. More about the power divider will be covered in later units.

DIDACTOR PLATES FOR AM 1-16D

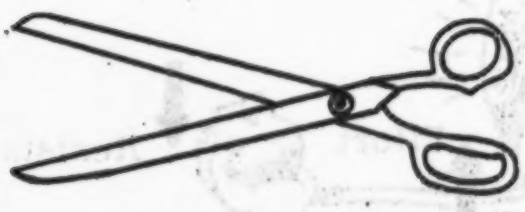
Levers of the FIRST class



Levers of the SECOND class

Levers of the THIRD class

Plate I The three classes of levers.



(a) small MA and rapid work

(b) large MA, slower accomplishment of task

Plate II

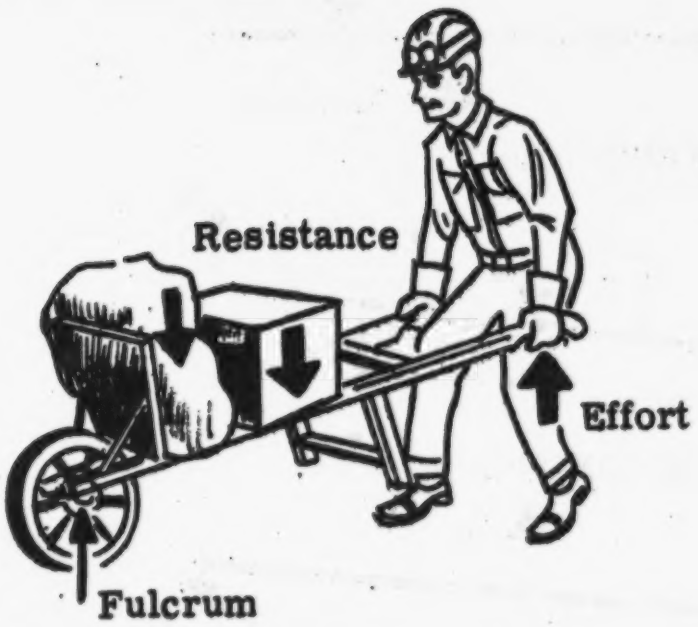


Plate III Levers of the second class.

Plate IV Examples of levers of the third class.

SAFETY WITH LEVERS -- When using a basic machine to increase mechanical advantage through an increase in force, we must always be aware of the hazards involved. In the case of moving heavy equipment with levers or pinch bars (which are levers), we should take note of the following conditions:

1. Is the lever heavy enough, or is it bowed? Will it be likely to bend or break?
2. Is the fulcrum stable, or will it move or tilt sideways so that the lever slips off?
3. Is the incline of the lever so steep that the material is pushed away or that the fulcrum moves back?
4. Are fingers and toes in the clear?
5. Has thought been given to securing the material as it is moved, or after it is moved?
6. Is the use of a lever the safest way of doing the job?

Plate V Safety with lever.

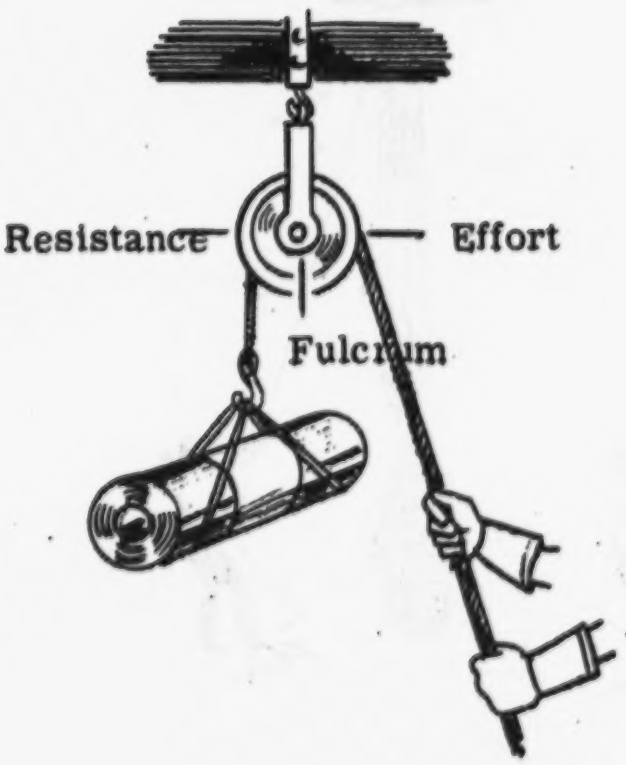


Plate VI Single fixed pulley.

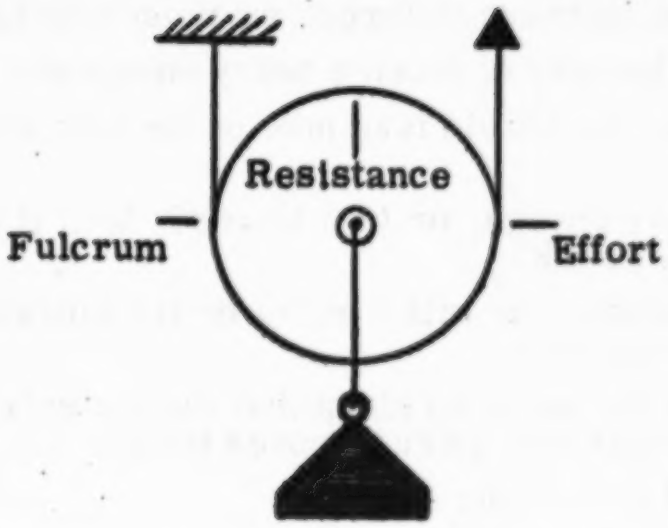


Plate VII Single movable pulley.

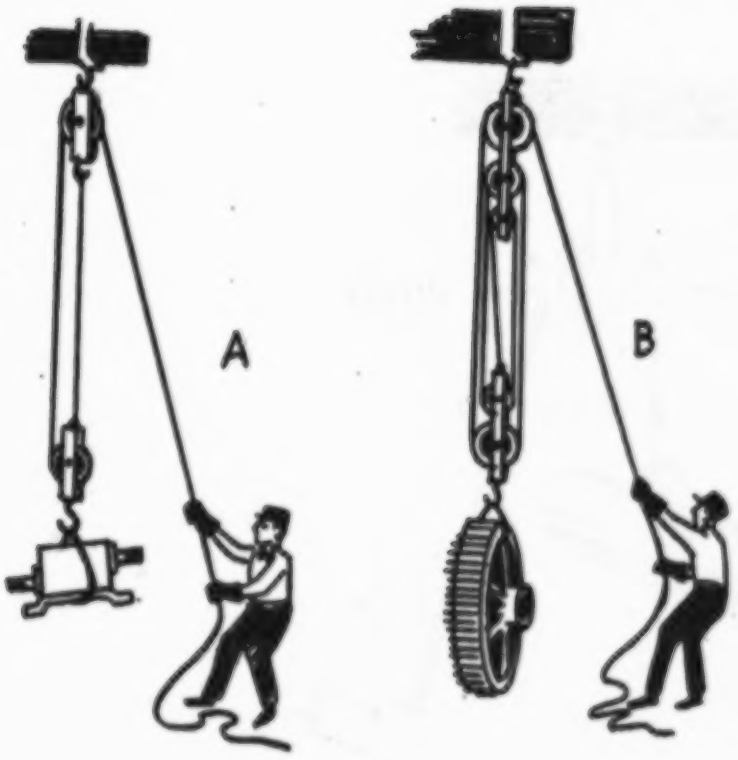


Plate VIII Block and tackle.

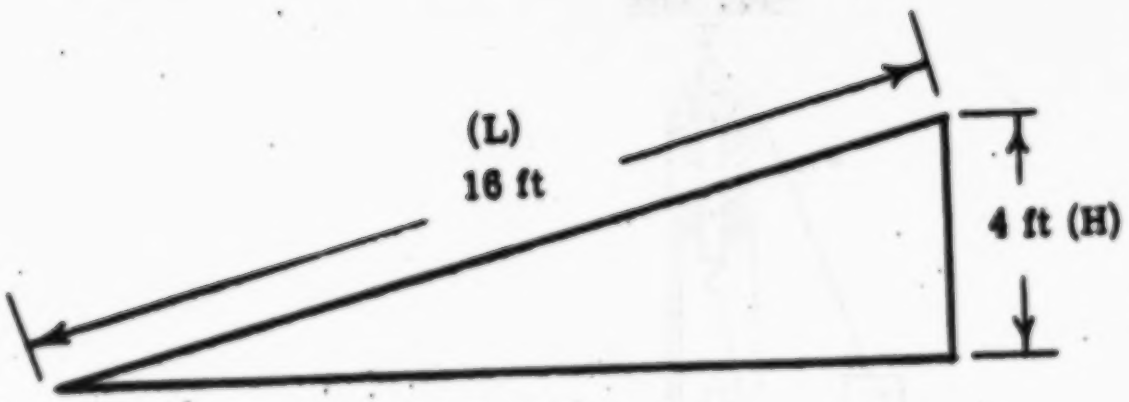


Plate IX Inclined plane.

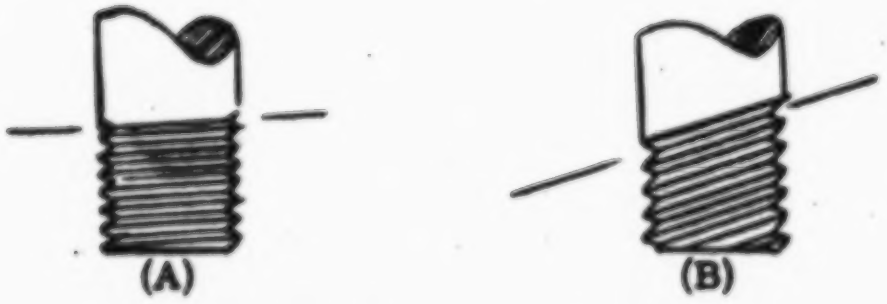
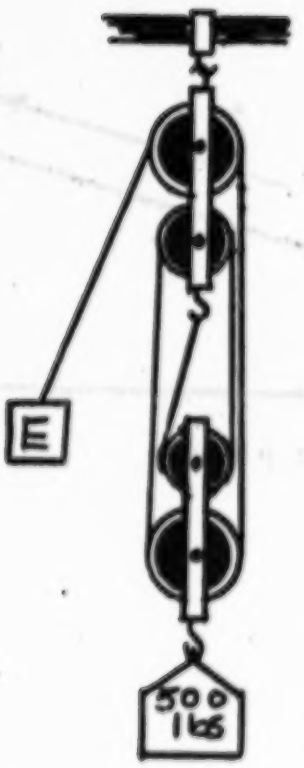


Plate X The threads in (B) have a steeper incline than the threads in (A). (A) has a greater mechanical advantage than (B).

Plate XI



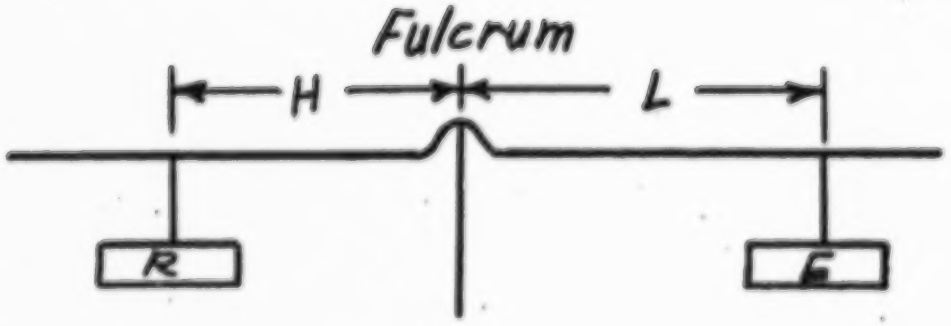


Plate XII Basic lever.

Plate XIII

FORMULAE

POWER

$$P = \frac{\text{work}}{\text{time}} \quad \text{or} \quad P = \frac{W}{T}$$

$$P \text{ (horsepower)} = \frac{\text{work (foot-pounds)}}{550 \text{ (one horsepower)} \times \text{time (seconds)}}$$

MECHANICAL ADVANTAGE

$$\text{Mechanical Advantage} = \frac{\text{effort arm}}{\text{resistance arm}} \quad \text{(or) MA} = \frac{L}{H}$$

$$\text{Mechanical Advantage} = \frac{\text{resistance}}{\text{effort}} \quad \text{(or) MA} = \frac{R}{E}$$

$$\text{Mechanical Advantage} = \frac{\text{effort distance}}{\text{resistance distance}} \quad \text{or MA} = \frac{ED}{RD}$$

$$\text{Mechanical Advantage} = \frac{\text{length of inline}}{\text{height of plane}} \quad \text{or MA} = \frac{L}{H}$$

SCREWS

Mechanical Advantage = circumference x pitch

(or) MA = circumference x pitch

Circumference (C) = πD

(or) C = 3.1416D

HUMAN ENGINEERING INSTITUTE

Development Department

INTEROFFICE CORRESPONDENCE

February 3, 1967

TO: Center Directors

RE: Errors on films MM 1-9, 1/10/66 and AM 1-16D, 4/15/66, entitled, "Understanding the Principles and Applications of Basic Machines"

Errors have been found on Frames 11 and 13 of these films, as shown on the attached Errata Sheet.

Please:

1. Make these corrections on the 8-frame repros in your possession, and

2. Issue an errata sheet with each of these films wherever used.

KLI

Karl L. Ireland
Editor

KLI:pb

MM 1-9D
1-10-66

AM 1-16D
4-15-66

ERRATA SHEET
2-3-67

When you are using the film entitled, "Understanding the Principles and Applications of Basic Machines", you should watch for these two frames (near the beginning of the film). They should read as shown here:

Let's return to our problem on the amount of work done in lifting the 20 pound box three feet off the ground. Let's say that it took two seconds to lift this weight this distance.

Substituting our values into this formula, $hp = \frac{W}{550 \times t}$ we have:

$hp = \frac{20 \times 3}{550 \times 2}$ $hp = \frac{60}{1100}$ hp = ~~.055 ft lbs per sec.~~ .055 horsepower

Take a good look at this formula. When you understand the formula and the problem,

Press A (#11)

No, you have made a mistake. The question was: how much horsepower would a 200 pound man use running up a 15 foot flight of stairs in 4 seconds?

Let's work the problem together:

$$hp \text{ (horsepower)} = \frac{W}{550 \times t \text{ (seconds)}}$$

$$hp \text{ (horsepower)} = \frac{200 \times 15}{550 \times 4} = \frac{3000}{2200} \quad hp \text{ (horsepower)} = 1.36$$

(550)

Study this problem until you understand it.

Press A

(#13)

DIDACTOR

FILM NO. AM 1-16D 4/15/66

0

AM 1-16D
4/15/66

PRINCIPLES AND APPLICATIONS OF BASIC MACHINES

Human Engineering Institute

Press A

Check to see that timer is OFF

-1

1

To most of us the word "machines" brings to mind automobiles, diesel engines, plant production equipment, or some other complex device. Actually, each of these large machines is made up of many smaller and simpler machines, the basic machines. These basic machines consist of levers, pulleys, wheel and axle, inclined plane, screws and wedges.

We will discuss the basic machines in terms of work, energy, and power. Each of us has an idea of what is meant when the words work, energy, or power are used. But to be able to understand and use the words properly when discussing mechanical relationships, we must define them as they are used by recognized authorities.

Press A 2

1

2

We usually think of "work" as holding up one end of a heavy plank or pushing against a stalled car even if we don't move the car. In the mechanical sense however, WORK is done only when a force succeeds in moving the body it acts upon. Therefore, we can see that no matter how tired we may get, no mechanical work has been done in the examples above.

Which of the below is an example of work ?

A. The wife failing to screw the lid off a pickle jar. 3
B. The husband screwing the lid off the pickle jar. 4
C. A pair of ladders holding up a 5000 pound scaffold. 1 3

3

Your answer is incorrect. We said that, in the mechanical sense, work is done only when a force succeeds in moving the body it acts upon.

Another way of saying this is that work is done only when a force succeeds in moving the force it is trying to move.

"The husband screwing the lid off the pickle jar" is the right answer.

No work is done when the wife fails to screw the lid off the pickle jar or when the ladders simply hold up the scaffold.

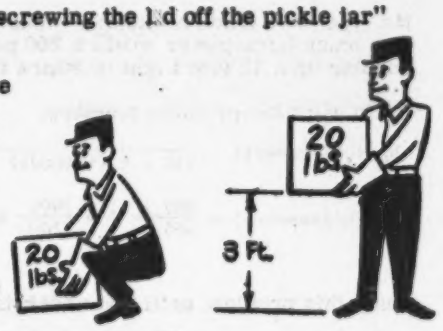
Press A 4

1

4

O.K., "the husband screwing the lid off the pickle jar" is the right answer.

Let's say that you are required to lift a 20 pound box a distance of 3 feet from the floor to a storage shelf.



This expression can be put into general terms by the formula:

Work = Force x Distance or : W = FD

Write this formula down and keep it handy. 1

Press A 5

5

How much work would be done? Using our formula, W = FD, we would have:

W = Force (20 lb) x Distance (3 ft)

W = 20 x 3 = 60 foot-pounds.

How much work would be done moving an 84 pound electric motor 5 inches?

A. 420 foot-pounds. 6
B. 35 inch-pounds. 5
C. 420 inch-pounds. 7

1

6

You have made a mistake. The formula is :

W = Force (84 lb) x Distance (5 in)

W = 84 x 5 = 420 inch-pounds

Notice that the answer must be expressed in the right distance term (inch in this case) and the right force term (pounds in this case).

Press A 7

1

7

O.K., 420 inch-pounds. In this problem we were using weight in pounds and distance in inches; so, our answer is in inch-pounds.

How much work would be required to lift an object weighing 20 grams to a height of 3 centimeters ?

A. 60 foot-pounds. 8
B. 60 inch-pounds. 8
C. 60 gram-centimeters. 8

1

8

Your answer is wrong. The formula is :

W = Force (20 centimeters) x Distance (3 grams)

W = 20 x 3 = 60 gram-centimeters.

In this problem we were using weight in grams and distance in centimeters; so, our answer is in gram-centimeters.

Press A 5

1

5

O.K., 60 gram-centimeters.

Having discussed the concept of work, we can go into the meaning of energy. Energy is the capacity or ability to do work.

Energy can be found in many forms. For example, chemicals in the food we eat, or in coal, or in the other fuels used in heating. Energy can also be found in flowing water or in a weight that is pushed off a table and falls to the floor.

Press A 10

1

10

POWER - Power may be defined as the rate of doing work, and is arrived at by dividing the amount of work done by the time taken to do the work.

This can be expressed by the formula:

$$P = \frac{\text{Work}}{\text{Time}} \quad \text{or} \quad P = \frac{W}{T}$$

HORSEPOWER - One horsepower is equal to 550 foot-pounds per second. Horsepower can be expressed by the formula:

$$\text{hp (horsepower)} = \frac{\text{Work (foot-pounds)}}{550 \text{ (one horsepower)} \times \text{time (seconds)}},$$

$$\text{or } hp = \frac{W}{550 \times t} .$$

Write down these formulas.

Press A 11

1

11

Let's return to our problem on the amount of work done in lifting the 20 pound box three feet off the ground. Let's say that it took two seconds to lift this weight this distance.

Substituting our values into this formula, $hp = \frac{W}{550 \times t}$ we have:

$$hp = \frac{20 \times 3}{550 \times 2} \quad hp = \frac{60}{1100} \quad hp = .055 \text{ ft lbs per sec.}$$

(.055 horsepower)

Take a good look at this formula. When you understand the formula and the problem,

Press A 12

1

12

Here's a problem. We all run up and down stairs.

How much horsepower would a 200 pound man use running up a 15 foot flight of stairs in 4 seconds?

A. 3000 horsepower. 13
B. 1.36 horsepower. 14
C. .735 horsepower. 13

1

13

No, you have made a mistake. The question was: how much horsepower would a 200 pound man use running up a 15 foot flight of stairs in 4 seconds?

Let's work the problem together:

$$\text{hp (horsepower)} = \frac{W}{550 \times t \text{ (seconds)}}$$

$$\text{hp (horsepower)} = \frac{200 \times 15}{500 \times 4} = \frac{3000}{2200} \quad \text{hp (horsepower)} = 1.36$$

Study this problem until you understand it.

Press A 14

1

14

O.K., the man would use 1.36 horsepower.

In order to discuss basic machines, we should first learn some special terms and their meanings. Here are the most important ones for our use in this unit: RESISTANCE is the force which an object exerts against any other force which is trying to move it. To illustrate; when a man tries to lift a 20 pound weight, the weight of the object exerts a resistance of 20 pounds against the lifting effort.

Press A 15

1

15

EFFORT is the force which is used to overcome resistance. In the following illustration, the force needed to lift the object, (20 pounds) would be the amount of effort needed. We may also speak of the amount of effort which a machine must exert in order to do a given amount of work.

This film will not move until you answer the question below correctly.

Which of the below is the correct formula for work (W)?

A. Work = Time x Force, (W = TF). —
B. Work = Force x Distance, (W = FD). 16
C. Work = Pounds x Force, (W = PF). —

1

16

Right. The correct formula for work is Work = Force x Distance, or W = FD.

RESISTANCE DISTANCE refers to the distance through which a resistance moves when it is acted on by an effort great enough to move it. In other words, it is the distance through which the resistance or load moves.

Which of the below illustrates resistance?

A. A man straining to lift a 30 pound weight. 17

B. A man lifting a 45 pound weight. 17

C. A 15 pound weight that something is moving or trying to move. 18

1

17

You have made a mistake. "A 15 pound weight that something is moving or trying to move" is the illustration of resistance.

RESISTANCE is the force which an object exerts against any other force which is trying to move it. To illustrate: when a man tries to lift a 20 pound weight, the weight of the object exerts a resistance of 20 pounds.

Press A 18

1

18

O.K., "A 15 pound weight that something is lifting or trying to lift" is the right answer.

EFFORT DISTANCE is used to refer to the distance through which an effort moves when it acts on a resistance which it is capable of moving.

Which of the below is the best illustration of effort?

A. A man straining to move a 150 pound weight and failing. 15

B. The amount of force necessary for a man to lift a 45 pound weight. 20

C. A 200 pound man trying to lift a 3650 pound car. 15

1

15

Your answer is incorrect. The best illustration of effort is, "the amount of force necessary for a man to lift a 45 pound weight."

EFFORT is the force which is used to overcome resistance. In the example above, the force needed to lift the object, (45 pounds) would be the amount of effort needed.

We may also speak of the amount of effort which a machine must exert in order to do a given amount work.

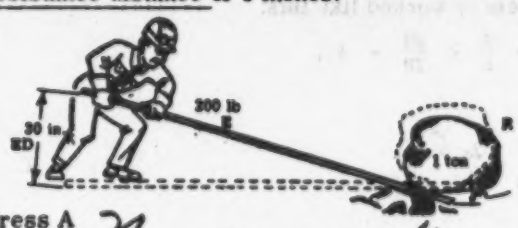
Press A 20

1

20

O.K., "the amount of force necessary for a man to lift a 45 pound weight" is the best illustration of effort.

An example of the use of these terms in describing basic machines can be seen below. To raise the stone, the man has to exert an effort of 200 pounds through an effort distance of 30 inches. While the stone is being lifted, it exerts a resistance of one ton against the end of the lever, and is moved a resistance distance of 3 inches.



1

Press A 21

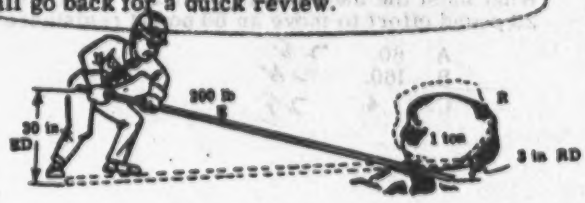
XC → 20½

20½

O.K., "the amount of force necessary for a man to lift a 45 pound weight" is the best illustration of effort.

An example of the use of these terms in describing basic machines can be seen below. To raise the stone, the man has to exert an effort of 200 pounds through an effort distance of 30 inches. While the stone is being lifted, it exerts a resistance of one ton against the end of the lever, and is moved a resistance distance of 3 inches.

If you have made one or more errors on the questions in this section - or - if this is your first time through it - we will go back for a quick review.



Press A → 2

21

LEVERS - A lever is probably the most simple form of basic machine. It is simply a solid rod pivoted on a fixed point called a FULCRUM.

What is resistance distance ?

A. The distance that the resistance moves the effort. 23

B. The distance that the resistance is moved by the effort. 23

C. The distance that the resistance carries the effort. 24

2

22

Your answer is wrong. "The distance that the resistance is moved by the effort" is the right answer.

RESISTANCE DISTANCE refers to the distance through which a resistance moves when it is acted on by an effort great enough to move it. In other words, it is the distance through which the resistance or load moves.

Press A 23

2

23

O.K., the right answer is "the distance that the resistance is moved by the effort."

Mechanical advantage (MA) is the number of times a machine increases the force which is applied to it. A certain amount of this advantage is lost through friction; but because friction is usually very minor, we will ignore it.

Complete the statement below correctly :
A _____ is probably the most simple form of basic machine. It is simply a solid rod pivoted on a fixed point called a fulcrum.

A. rope 24
B. pulley 29
C. lever 25

2

24

No, you have made a mistake. Lever is the correct answer.

A lever is the most simple basic machine. It is simply a solid rod pivoted on a fixed point called a fulcrum.

Press A 25

2

25

O.K., the lever, the simplest basic machine, is simply a solid rod pivoted on a fixed point called a fulcrum.

If, by using a machine, a man is able to lift a 100-pound weight by using a force of only 10 pounds, we say that the machine has a mechanical advantage of 100 ÷ 10 or 10.

Which machine below has the greatest mechanical advantage?

A. A lever which moves a 30, 000 pound railroad car with a force of 150 pounds. 27
B. Tin snips which change a 6 pound force into a 20 pound force. 26
C. A man tossing a 40 pound bag with a 200 pound force. 26

2

26

Your answer is wrong. "A lever which moves a 30, 000 pound railroad car with a force of 150 pounds" is the right answer.

If, by using a machine, a man is able to lift a 100 pound weight by using a force of 10 pounds, we say that the machine has a mechanical advantage of 100 ÷ 10 or 10.

Mechanical advantage (MA) is the number of times a machine increases the force which is applied to it.

Press A 27

2

27

O.K., the right answer is "a lever which moves a 30, 000 pound railroad car with a force of 150 pounds."

The mechanical advantage of a lever can be found in several ways. Let's look at one: $MA = \frac{R}{E}$, or mechanical advantage equals the resistance divided by the effort.

The mechanical advantage of the lever-railroad car problem above is: $MA = \frac{R}{E} = \frac{30,000}{150} = 200.$

What must the mechanical advantage be in order for a 20 pound effort to move an 80 pound resistance?

A. 60. 28
B. 160. 28
C. 4. 29

2

28

You have made a mistake. The mechanical advantage must be at least 4 in order for a 20 pound effort to move an 80 pound resistance.

The problem is worked like this:

$MA = \frac{R}{E} = \frac{80}{20} = 4.$

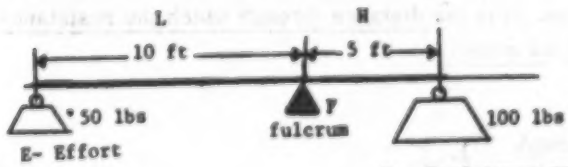
Press A 29

2

29

O.K., the mechanical advantage must be at least 4.

The part of the lever extending between the fulcrum and the point at which the effort is applied is known as the effort arm (L). The resistance arm(H) is the part that extends between the fulcrum and the point at which the resistance is placed.



Press A 30

2

30

If the lengths of the two arms are known, the MA of the lever can be found by dividing the length of the effort arm (L) by the length of the resistance arm (H).

For example, $MA = \frac{L}{H} = \frac{10}{5} = 2.$

What is the mechanical advantage (MA) if the effort arm (L) is 15-feet long and the resistance arm is 3 feet long (both arms are in balance).

A. 45. 31
B. 12. 31
C. 5. 32

2

35

No, you have made an error.

We know that only one half of the resistance weight (R= 700 pounds) is needed, because the mechanical advantage (MA) is 2.

The film will move only when you press the right answer to the question below.

Find the effort ~~needed to lift~~ a 700 pound weight if the MA = 2.

A. 350 pounds. -40
B. 400 pounds. —
C. 700 pounds. —

2

40

Very good. You have now completed the section on levers and mechanical advantage.

We will now discuss classes of levers and the mechanical advantage of pulleys and gears.

CLASSES OF LEVERS - There are three classes of levers. The class into which any one lever falls depends on the relative positions of the fulcrum, the effort, and the resistance, as seen in Plate I in MM 1-9.

Press A 42

XC → 41

2

41

Very good, your answer is right. We need a 350 pound effort to lift a resistance of 700 pounds, because the mechanical advantage is 2.

You have completed the introduction to levers and mechanical advantages. We discussed the concepts of work, energy, power, horsepower, and how they are used by the mechanical maintenance man.

You have made one or more mistakes in this section; we will now review.

Press A → 21

2

42

LEVERS OF THE FIRST CLASS have the fulcrum between the effort and the resistance. The position of the fulcrum in relation to the effort and the resistance will determine the mechanical advantage of levers of the first class.

If the effort arm is longer than the resistance arm, the MA is greater than 1. If the effort arm is shorter than the resistance arm, the MA is less than 1. All of the levers we have previously described are levers of the first class.

Applied examples of levers of the first class are pliers, shears, tin snips, pump handles, two wheeled hand trucks, etc.

Press A 43

3

43

When the object is to save time, and not much effort is required, the effort arm can be shorter than the resistance arm. If much effort is required, more time will be taken to do the work, and the effort arm should be longer than the resistance arm. Good examples of this are paper shears and sheet-metal shears. See Plate II.

What class of lever are the scissors and tin snips ?

A. Second class lever. 44
B. First class lever. 45
C. Third class lever. 44

3

44

Your answer is incorrect. Scissors and tin snips are first class levers.

The blades of these tools are the resistance arms and the handles are the effort arms.

Since the work done with scissors is easy, the resistance arm is long and the effort arm is short in order to save time.

Because the work done with tin snips is harder, however, the resistance arm is short and the effort arm is longer in order to furnish more power to do the work.

Press A 45

3

45

O.K., scissors and tin snips are first class levers.

The effort needed to cut paper is small, and since the hand can exert much more force than is needed, the excess is employed by making the handles short and the blades long, so the paper can be cut more quickly.

However, when using the metal shears, great effort is needed to cut the metal, and therefore the handles are made longer and the blades shorter so that you cut more slowly but apply a greater force.

Describe a lever of the first class.

A. The resistance is between the fulcrum and the effort. 46
B. The effort is between the fulcrum and the resistance. 46
C. The fulcrum is between the effort and the resistance. 47

46

You have made a mistake. For a lever of the first class, the fulcrum is between the effort and the resistance.

Now what does this mean to us ? It means that a lever of the first class is like a see-saw or teeter-totter. On a teeter-totter, the fulcrum (the bar that supports the load) is between the resistance (the load on one end) and the effort (the load that supports or balances the resistance).

Examples of levers of the first class are pliers, shears, tin snips, pump handles, two wheeled hand trucks, and scissors.

Press A 47

3

4?

O.K., the fulcrum of a lever of the first class is between the resistance and the effort.

LEVERS OF THE SECOND CLASS have their resistance located between the fulcrum and the effort. The mechanical advantage of levers of the second class is always greater than 1 because the effort arm is always longer than the resistance arm. See Plate I (A) and Plate III.

What do we mean when we say "mechanical advantage is always greater than 1."

A. The effort needed to lift an object is smaller than the resistance. 4S
B. The resistance arm is larger than the effort arm. 4S
C. The resistance and effort arm are sometimes the same length. 4S

3

4S

No, you have made an error. The effort needed to lift an object is always smaller than the resistance when the mechanical advantage is greater than 1.

When we say that "the mechanical advantage is always greater than 1" on a lever, we mean that the resistance arm is smaller than the effort arm not larger or the same length.

What does this mean? Here's an example. On a nutcracker, the handle is always longer than the round part that holds the nut.

Press A 4?

3

4?

O.K., the effort needed to lift an object is smaller than the resistance when the mechanical advantage is greater than 1.

Mechanical examples of levers of this class are nutcrackers, wheelbarrows, arbor presses and throttle or hand-brake control handles on many machines. A pinch bar can act as either a first or second class lever, depending on how it is used. See Plate III.

Now, describe a lever of the second class.

A. The effort is between the resistance and the fulcrum. 5-0
B. The resistance is between the fulcrum and the effort. 5-1
C. The fulcrum is between the effort and the resistance. 5-0

3

5-0

Your answer is wrong. For a lever of the second class, the resistance is between the fulcrum and the effort.

What does this mean? Here's an example. The wheel of a wheelbarrow is the fulcrum. The resistance (load) is placed between the wheel and the part of the handle where we hold the wheelbarrow.

The closer we hold a wheelbarrow to the end and the closer we place the load to the front (near the wheel) -- the greater will be the mechanical advantage.

Press A 5-1

3

5-1

O.K., the resistance is between the fulcrum and the effort on a second class lever (see Plates I and III).

LEVERS OF THE THIRD CLASS always have their effort located between the fulcrum and the resistance. Some examples of third class levers are, shovels, tweezers, and fishing poles.

The mechanical advantage of a third class lever is always less than 1 because the effort arm is always shorter than the resistance arm. Note the positions of the fulcrum in Plate IV.

Press A 5-1½

3

5-1½

We use two arms in shoveling. Why does one arm get more tired than the other?

A. Because one arm (the effort arm) does the work. The other arm just balances the shovel. 5-3
B. Because we are doing the job wrong. If we did it right, we wouldn't get tired. 5-2
C. Because the shovel is broken. 5-2

3

5-2

Your answer is incorrect, see Plate IV.

We use two arms for shoveling. One arm gets more tired than the other because one arm (the effort arm) does the work. The other arm (the fulcrum) just balances the shovel.

Press A 5-3

3

5-3

O.K., the effort arm gets tired because it does the work.

PULLEYS - A SINGLE FIXED PULLEY, is similar to one we might use to raise roofing materials to the roof top. It is simply a continuous lever of the first class, with resistance and effort arms of equal length. Therefore, the mechanical advantage of a single fixed pulley is 1. It is used only to change the direction -- we pull in 1 foot of cord and the resistance, or load, moves 1 foot. See Plate VI.

The film will not move until you answer the question below correctly.

How many times is the effort multiplied if the mechanical advantage is 1 ?

A. 1 + 1, or twice.
B. The effort is not multiplied because the resistance equals the effort applied. 5-4

3

You are right. The effort is not multiplied because the resistance equals the effort.

The fixed pulley or a combination of fixed pulleys is used to make possible tasks that would otherwise be impracticable. An example can be found in the use of a pulley at the top of a flag pole. Obviously, it is more practicable to pull down on a rope than it is to climb the pole and pull the flag to the top!

What is achieved using a single fixed pulley.

A. Increase in mechanical advantage.
B. Decrease in mechanical advantage.
C. Convenience.

3

Your answer is incorrect. We achieve convenience in the use of a single fixed pulley.

Single fixed pulleys are used to raise roofing material to roof tops. The fixed pulley or a combination of fixed pulleys is used to make possible other tasks that would be impractical.

For example, there is a pulley on a flag pole because it is easier to pull down on a rope than it is to climb the pole and pull the flag up!

Press A

3

O.K., a single fixed pulley gives us convenience.

A SINGLE MOVABLE PULLEY, as shown in Plate VII, is simply a lever of the second class with the resistance located between the fulcrum and the effort.

We note here that the effort arm is twice as long as the resistance arm. If we were to pull up a 2 foot length of effort cord the pulley would move up 1 foot.

What is the mechanical advantage of this pulley ?

A. 2.
B. 1.
C. 1/2

3

No, you have made a mistake. The mechanical advantage of this pulley is 2.

Why ?

Because the effort arm is twice as long as the resistance arm. If we were to pull up a 2 foot length of effort cord the pulley would move up 1 foot.

Press A

3

O.K., the mechanical advantage of this pulley is 2.

Notice the two supporting strands. A quick way of determining the MA of any pulley system is to count the number of strands of rope supporting the weight being lifted. The MA of the pulley system is equal to this number.

Single movable pulleys sometimes are used to increase the mechanical advantage, but more often they are used to make work more convenient by changing the direction of force.

Press A

3

A BLOCK AND TACKLE is a group of fixed and movable pulleys that are arranged to increase the mechanical advantage.

As we previously learned, the MA of a pulley system can be found by counting the number of strands supporting the weight to be lifted. Looking at Plate VIII (a), we can see that the MA of the block and tackle in "a" is 2. What is the MA in Plate VIII (b)?

A. 6.
B. 3.
C. 5.

3

Your answer is incorrect. The mechanical advantage of a pulley system can be found by counting the number of strands supporting the load.

Look at Plate VIII.

There are 5 strands supporting the load. You should not count the SIXTH strand as this one only changes the direction of the pull. Therefore, the mechanical advantage of the block and tackle in Plate VIII (b) is 5.

Press A

3

O.K., the MA of the block and tackle in Plate VIII (b) is 5.

If the weight of the resistance in Plate VIII (a) is 200 pounds, what amount of effort would be required to lift this weight ? Using our formula:

$$\text{Effort} = \frac{\text{Resistance}}{\text{Mechanical Advantage}} \quad \text{or} \quad E = \frac{R}{MA}$$

We find: $E = \frac{200}{2} = 100$

What effort would be required to lift the same weight in Plate VIII (b)?

A. 5.
B. 40.
C. 100.

3

62

Your answer is wrong. We know that the MA of the block and tackle is 5. Using our formula :

$$\text{Effort} = \frac{\text{Resistance}}{\text{Mechanical Advantage}} \quad \text{or} \quad E = \frac{R}{MA}$$

We find : $E = \frac{200}{5} = 40$.

Press A 63

3

63

Right, an effort of 40 pounds would be required.

Now let's go on to some new material.

Press A 64½

→ 64

3

64

O.K., an effort of 40 pounds would be required.

If this is your first time through this part or if you've made one or more mistakes you will now review.

Press A → 43

3

64½

SAFETY WITH PULLEYS AND BLOCK AND TACKLE -

Let's take a look at some of the things we have to consider when working with pulleys or a block and tackle.

1. Is the cable strong enough? Don't forget that an MA of 12 means that the tension you feel when pulling on the cable is 12 times greater at the load.
2. Have you put locks on the cable so the load doesn't get away ?
3. Is the load balanced and in control at all times ?
4. Can the cable or rope slip and burn or cut your hands? Gloves should be worn where practicable.

Press A 65

4

65

INCLINED PLANE - Next to the lever, the inclined plane is used more often in everyday life than any other type of machine. A basic inclined plane consists of a plank and a blocking to raise one end of the plank to a higher level than the other end. It is commonly used to raise objects that would be too heavy to raise directly by hand.

It is believed that the Egyptians made use of the inclined plane by building sloping hills of earth to haul the heavy stones to the higher parts of the pyramids. In our own daily life we can see many examples of the inclined plane. One example is found in its use on our highways and on ramps or stairways. Another example, is its use in moving heavy barrels onto a trucking or loading platform.

Press A 66

4

66

The mechanical advantage of an inclined plane is computed by dividing the length of the plane by its height. In Plate IX, the MA would be 4.

$$MA = \frac{l}{H} = \frac{16}{4} = 4$$

What is the mechanical advantage of a plane if the length of the plane is 11 feet and the height of the plane is 4 feet ?

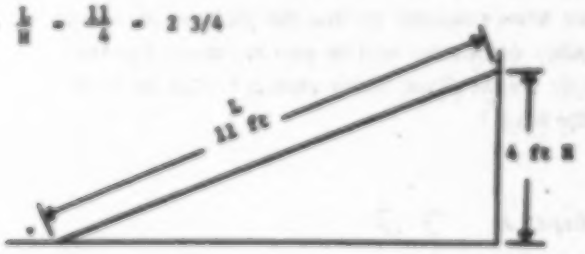
A. 4. 67
B. 2 3/4. 68
C. 11 69

4

67

No, you have made a mistake. In this figure the MA would be :

$$MA = \frac{l}{H} = \frac{11}{4} = 2\ 3/4$$



Press A 68

4

68

O.K., the MA is 2 3/4.

We must remember that friction, such as that encountered when pushing a flat object up the plane, can greatly reduce the efficiency obtained. However for purposes of illustrating the forces involved, we have neglected this element of friction.

In Plate IX, what effort would be needed to push a 200 pound weight (resistance) up the incline ? The effort required can be computed as follows:

$$\text{Effort} = \frac{\text{Resistance}}{\text{Mechanical advantage}} \quad \text{or} \quad E = \frac{R}{MA}$$

Complete the computation and select the correct answer below.

A. 200 pounds. 65
B. 4 pounds. 65
C. 50 pounds. 70

4

55

Your answer is incorrect.

If Effort = $\frac{\text{Resistance}}{\text{Mechanical Advantage}}$ or E = $\frac{R}{MA}$

then E = $\frac{300}{4}$ E = 30 pounds

Press A 70

4

70

O.K., an effort of 50 pounds would be needed.

CONSTRUCTING AN INCLINED PLANE - If you were to construct an inclined plane, you would have two things to consider:

1. How much effort you wish to exert to move the object up the plane, and,
2. The amount of time you wish to take to move the object up the plane.

In Plate IX what effort would be needed to push a 300 pound weight (resistance) up the incline ?

A. 300 pounds. 71
B. 50 pounds. 71
C. 75 pounds. 72

4

71

No, you have made an error.

If Effort = $\frac{\text{Resistance}}{\text{Mechanical Advantage}}$ or E = $\frac{R}{MA}$.

then E = $\frac{300}{4}$ E = 75 pounds

Press A 72

4

72

O.K., the effort required is 75 pounds.

If the length of the plane in Plate IX were doubled to 32 feet, the MA would be increased to 8. It would then be much easier to push the object up the plane, but this would be done at the expense of added time, unless you moved faster. How much effort would be required in the above illustration ?

How much effort would be required to move 300 pounds (resistance) up the incline?

A. 75 pounds. 73
B. 37 1/2 pounds. 74
C. 33 1/3 pounds. 73

4

73

Your answer is wrong. The MA is 8.

If Effort = $\frac{\text{Resistance}}{\text{Mechanical Advantage}}$ or E = $\frac{R}{MA}$

then E = $\frac{300}{8}$ E = 37 1/2 pounds.

Press A 74

4

74

O.K., the effort required is 37 1/2 pounds.

USING AN INCLINED PLANE - In deciding on the use of an inclined plane to get a job done, you should consider the following:

1. The weight and shape of the object.
2. The amount of time you have to do the job.
3. Whether or not the equipment available is sturdy enough for the job. Is the plank heavy enough ? Will the load get away from you ?
4. Can you block the object as you push or pull it up the plane?
5. Is enough manpower available ?
6. Have you got a good footing on the plane or is the incline too steep ?

Press A 75

4

75

A WEDGE is another type of inclined plane that may be considered as two inclined planes with their bases fastened together as seen here. Nearly all cutting and piercing tools are wedges: knives, chisels, carpenter's planes, awls, nails, pins, and needles.

What things must we consider so that the inclined plane and other equipment will be sturdy enough for the job ?

A. Whether we are lifting steel or brass. 76
B. Whether we are lifting glass or not. 76
C. Is the plank heavy enough ? Can we hold the load ? 77

4

76

Your answer is incorrect. These are the things we must consider so that the inclined plane and other equipment will be sturdy enough for the job: Is the plank heavy enough? Can we hold the load ?

Press A 77

4

77

Wedges often are used to raise objects by being forced under them as in the use of a crowbar, or to separate two objects as in splitting wood with an axe.

The mechanical advantage of a wedge (neglecting friction) is found by dividing the length of its taper by its maximum thickness. While the efficiency of a wedge is very low because of the large amount of friction, the friction is beneficial in that it helps to keep the wedge in place.

Press A 78

78

SCREW - One of the most familiar of the simple machines is the common screw. The construction of the screw's thread is based on the principle of the inclined plane. A screw's thread is simply a coiled inclined plane winding around the body of the screw.

How is the mechanical advantage of a wedge found?

A. By dividing one side of the taper by the other tapered side. 75
B. By dividing the maximum thickness by the length of its taper. 75
C. By dividing the length of its taper by its maximum thickness. 80

75

No, you have made an error.

The mechanical advantage of a wedge (neglecting friction) is found by dividing the length of its taper by its maximum thickness. While the efficiency of a wedge is very low because of the large amount of friction, the friction is beneficial in that it helps to keep the wedge in place.

Press A 80

80

O.K., by dividing the length of its taper by its maximum thickness.

A screw with fewer threads-per-inch than another would have a steeper incline and, as we will see, less mechanical advantage, because of the shorter length of the coiled thread. Plate X. On any screw this number of threads per linear inch is known as the pitch of the screw. The pitch of a 5/8-11 NC thread would be 11.

What is the important relationship of a screw to an inclined plane?

A. They both can be made of metal. 81
B. A screw is simply a coiled inclined plane. 82
C. A screw fastens things down and you move something on inclined planes. 81

81

No, you have made a mistake.

A screw's thread is simply a coiled inclined plane winding around the body of the screw. A screw with fewer threads-per-inch than another would have a steeper incline and, as we will see, less mechanical advantage, because of the shorter length of coiled thread.

Press A 82

82

O.K., a screw's thread is simply a winding inclined plane.

The mechanical advantage of a screw can be figured by:

1. Dividing the total length of the unwound thread by the length of the threaded portion of the screw. The length of the (unwound) thread corresponds to the length of the plane (L), Plate IX, while the length of the threaded portion of the screw corresponds to the height of the plane (H). or-
2. Multiply the circumference of the thread by the pitch of the screw.

Which screw below has the greater mechanical advantage (they are the same length)?

A. A screw with less threads per inch. ———
B. A screw with more threads per inch. 84

(Film will move only when you select the correct answer.)

XC → 83

83

Right, the screw with the more threads-per-inch has the greater mechanical advantage.

In this section, we have studied some of the basic machines, the inclined plane, the wedge, and screw.

We have also learned a new formula for mechanical advantage:

$MA = \frac{L}{E}$ where MA is the mechanical advantage, L is the effort arm, and E is the resistance arm.

You have made one or more mistakes in this section; so you will now go back and review this material.

Press A → 66

84

Right, the screw with the more threads-per-inch has the greater mechanical advantage.

The mechanical advantage of a 5/8-11 NC thread would be:

Circumference = πD = 3.1416 x 5/8 = 1.96
MA = Circumference x Pitch
MA = 1.96 x 11
MA = 21.56

Because of the large amount of friction, the efficiency of a screw is very low, but this is not entirely a disadvantage for it prevents the screw from turning backward. This increased friction is one reason you will always find a screw with a greater number of threads per inch used where there is a high amount of vibration, such as aircraft parts.

Press A 81

Frame 5

Below are some practice problems that you should be able to do by using the formulas given in Plate XIII. As you do them, remember that you are disregarding friction, which is always present in varying degrees depending on the type of basic machine.

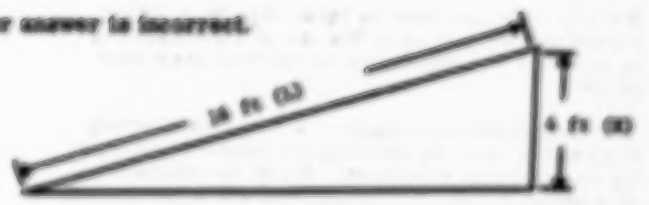
One end of a plank, 16 feet long, is 4 feet higher than the other end. A barrel weighing 120 pounds is being pushed up the plank. What is the mechanical advantage?

A. 16. → Frame 6
B. 120. → Frame 4
C. 4. → Frame 7

5

Frame 6

Your answer is incorrect.



$MA = \frac{L}{H} = \frac{16}{4} = 4.$

Press A → Frame 7

5

Frame 7

O.K., the MA is 4.

Now, what effort is necessary to push the barrel up the plank (remember the barrel weighs 120 pounds)?

A. 120 pounds. → Frame 8
B. 30 pounds. → Frame 9
C. 4 pounds. → Frame 8

5

Frame 8

Your answer is wrong.

We know that the MA is 4. We must find the effort.

The Effort = $\frac{\text{Resistance}}{\text{Mechanical Advantage}}$ or $E = \frac{R}{MA}$

Thus $E = \frac{120}{4}$ or $E = 30$ pounds.

So, the answer is that the effort required is 30 pounds.

Press A → Frame 6

5

Frame 9

O.K., the effort required is 30 pounds.

Now find the mechanical advantage (MA) and effort of the pulley system in Plate XI.

A. MA = 4, Effort = 125 pounds. → Frame 11
B. MA = 5, Effort = 100 pounds. → Frame 10
C. MA = 4, Effort = 500 pounds. → Frame 10

5

Frame 10

Your answer is incorrect. The mechanical advantage (MA) of a pulley system can be found by counting the number of strands supporting the load.

Look at Plate XI.

There are 4 strands supporting the load. Therefore, the mechanical advantage (MA) of the pulley system in Plate XI is 4.

The Effort = $\frac{\text{Resistance}}{\text{Mechanical Advantage}}$ or $E = \frac{R}{MA}$

Thus $E = \frac{500}{4}$ or $E = 125$ pounds.

Press A → Frame 11

5

Frame 11

O.K., the MA = 4, and the Effort = 125 pounds.

If the resistance weight in the preceding problem is raised 2 feet, through what distance does the effort move?

A. 2 feet. → Frame 12
B. 8 feet. → Frame 12
C. 4 feet. → Frame 12

5

Frame 12

No, you have made an error. The mechanical advantage of the pulley system in Plate XI is 4. This means that the effort must be only one-fourth the weight of the resistance. However, it also means that the effort must move 4 times as far as the resistance!

Now, if the resistance moves 2 feet, the effort must move 4 times as far, or 8 feet.

Press A → Frame 5

5

53

O.K., the effort moves 6 feet.

Now, refer to Plate XII to work the next four problems. Three values are given for each lever problem. You are to find, among other things, the value that will balance the lever. (You may draw your own figure if that helps.)

Given:
E = 300 grams
E = 4 inches
L = 6 inches

Find:
(1) E = _____
(2) MA = _____

A. (1) E = 300 grams (2) MA = 3/2 or 1 1/2. 51
B. (1) E = 300 grams (2) MA = 6 54
C. (1) E = 450 grams (2) MA = 2/3. 52

5

54

Your answer is incorrect. The effort (E) times the effort arm (L) equals the resistance (R) times the resistance arm (R).

The formula is: E x L = R x R. We know that:

Given:
E = 300 grams
R = 4 inches
L = 6 inches

Find:
(1) E = _____
(2) MA = _____

Therefore, E x L = R x R
E x 6 = 300 x 4 = 1200
E = 1200/6 = 200 grams

MA = 1/6
MA = 4/6
MA = 3/2 or 1 1/2

5

Press A 51

51

O.K., (1) E = 300 grams (2) MA = 3/2 or 1 1/2.

Refer to Plate XII (you may draw your own figure if that helps).

Given:
E = 220 grams
L = 3 inches
R = 11 inches

Find:
(1) MA = _____
R = _____

A. MA = 11/3, R = 606 2/3 56
B. MA = 3/11, R = 60 57
C. MA = 3, R = 660 52

5

56

No, you have made an error.
Here is a restatement of the problem:

Given:
E = 220 grams
L = 3 inches
R = 11 inches

Find:
(1) MA = _____
R = _____

MA = L/R = 3/11.

E x R = E x L
E x 11 = 220 x 3 = 660
E = 60.

Press A 57

5

57

O.K., the MA is 3/11 and R is 60.
You may refer to Plate XII or draw your own figure if that helps.

Given:
MA = 4
E = 400 grams
L = 12 inches

Find:
(1) E = _____
(2) L if R is 2 inches = _____

A. (1) E = 4 (2) L = 12. 55
B. (1) E = 100 (2) L = 8. 58
C. (1) E = 480 (2) L = 12. 58

5

58

No, you have made a mistake. This is the problem:

Given:
MA = 4
E = 400 grams
L = 12 inches

Find:
(1) E = _____
(2) L if R is 2 inches_____.

Using the formula: MA = R/E or E = R/MA we find:

E = 400/4 = 100 grams

When the resistance moves 2 inches (R), the effort will move MA times 2 inches. Therefore, L = 8 inches.

Press A 55

5

55

O.K., E = 100 grams and L = 8 inches.

Given:
E = 50 grams
E = 100 grams
R = 2 inches

Find:
(1) L = _____
(2) MA = _____
(3) Distance E moves, if R moves 3 inches = _____

A. (1) L = 4 (2) MA = 2 (3) E moves 6 inches. 100
B. (1) L = 1 (2) MA = 1/2 (3) E moves 1 1/2 inches. 101
C. (1) L = 4 (2) MA = 4 (3) E moves 3 inches. 100

5

100

No, you have made a mistake.

The effort (E) times the effort arm (L) equals the resistance (R) times the resistance arm (R). The formula is E x L = R x R. We know

that: E = 50 grams, E = 100 grams, R = 2 inches, therefore, 100 x L = 50 x 2, 100 x L = 100, L = 1.

The formula for mechanical advantage (MA) is: MA = L/R, MA = 1/2.

If the MA is 1/2, the effort moves 1/2 the distance of resistance, or 1 1/2 inches.

Press A 101

5

DIDACTOR

FILM NO. AM 1-16D 4/15/66

101

Very good, your answer is right; L = 1, MA = 1/2, and E moves 1 1/2 inches.

We have learned how basic machines such as levers, pulleys, inclined planes, screws and wedges are used. They are used to increase or decrease force, increase or decrease speed, or change energy from one form to another. We now have a better understanding of why the equipment and tools we work with every day are designed the way they are.

You have now completed this program.

Please rewind and turn off the machine.

5

XC → 102

102

O.K., the right answer is: L = 1, MA = 1/2 and E moves 1 1/2 inches.

We have learned how basic machines such as levers, pulleys, inclined planes, screws and wedges are used. They are used to increase or decrease force, increase or decrease speed, or change energy from one form to another. We now have a better understanding of why the equipment and tools we work with every day are designed the way they are.

If you have made one or more errors, therefore, you will now go back and review this section.

Press A

→ 85

5

INSTRUCTOR'S GUIDE

Title of Unit: I - Use and Care of Small Hand Tools

II - Principles of the Power Divider

AM 1-16
5/9/66

SPECIAL NOTE TO INSTRUCTOR:

This unit is very basic material on hand tools and could be inserted almost anywhere in the course. Use it where you feel it could apply.

FIRST:

Be sure all questions have been answered that students might have on home study units.

OBJECTIVES:

1. To review the use and care of small hand tools which are very important to the diesel mechanic. Also to explain torque again in a different manner.
2. Briefly discuss the power divider, it's purpose and operation.

LEARNING AIDS suggested:

The Williams Company, manufacturers of small tools, has strip films and records, plus handout sheets that are available for use. These films are excellant. For use of these films write to J. H. Williams Co., 400 Vulcan St., Buffalo, N. Y.

"The ABC of Hand Tools" 16 mm Film; runs 33 min. Write to General Motors Corporation, Public Relations Staff - Film Library, General Motors Building, Detroit, Michigan (48208).

Didactor Tape: AM 1-16D, "Understanding the Applications of Basic Machines".

Any small tools that can be brought into class and demonstrated, as discussed in the unit, would be helpful.

DISCUSSION IDEAS AND QUESTIONS (Designed to get participation and involvement of as many people in the class as possible.)

1. Why are torque wrenches used?
2. How is torque measured?
3. Why is an understanding of torque important when tightening fasteners?
4. What is torque? What does it have to do with wrenches?
5. What do these words mean?
   a. open-end wrench
   b. box or box-end wrench
   c. combination wrench
   d. socket wrench
   e. single open-end adjustable or crescent wrench
   f. setscrew and hollow-head capscrew wrench
   g. adjustable pipe wrench
   h. torque wrench
6. How would a combination box and open-end wrench be used where the nut is in a spot where it couldn't be spun off by finger pressure?
7. Where should a wrench be held for the best leverage?
8. To which jaw would the pulling force be applied to when using an adjustable wrench?
9. Why are common open-end wrenches made with the ends at an angle?
10. Why is it advisable not to push on a wrench to tighten or loosen a fastener?
11. What is the difference between a tap and tap drill?
12. What is the screw extractor and how is it used?
13. How should a chisel be used safely?
14. Why should a handle always be used on a file?
15. Why shouldn't a file be held against the work on the back stroke?
16. What two functions does a taper pin serve?
17. What procedure is used to ready a hole for a taper pin?